Instruments

THE MAGAZINE OF Measurement and Control

Vol. 12
DEC.
1939
No. 11

The Service of Temperature Supervision in YOUR Plant

A COMPLETE LINE OF TAG RECORDER - CONTROLLERS WITH 9", 10" & 12" CHARTS AND MODELS FOR "ON-OFF" AND THROTTLING CONTROL!

Today, TAG offers a complete line of modern Recorder-Controllers, using 9", 10" and 12" charts to satisfy economically and with certainty every industrial requirement for the measurement and control of process temperatures.

These famous Air-operated Control Instruments embody all the exclusive, modern TAG features with the dependable precision which has become a TAG tradition. The flapper mechanism has been redesigned and is now available in either "ON-OFF" Control Models for most industrial needs or Throttling Types for service where apparatus lag is present.

Ask for your copy of Catalog 1060-I . . . learn about the exceptionally long pen travel in these Recorder-Controllers and TAG's ingenious, interchangeable tube system. You'll also see why, throughout Industry where the maintenance of product quality and uniformity is the watchword, the TAG imprimatur is to be seen on panel boards in steadily increasing numbers.

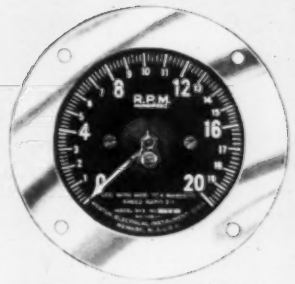
C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG LIABUE BROOKLYN N.Y. U.S.A.

PRECISION PORTABLES

(Electrodynamometer type accurate within ¼ of 1%) for critical test work. Available for AC and DC in Voltmeters (single, double and triple range), Ammeters, Milliameters, Wattmeters, etc.



ELECTRIC TACHOMETERS

Indicators calibrated in R.P.M. or in other units. Widely used on pumping and conveyor systems, ovens, kilns, etc. Several indicators can be mounted to one magneto, and mounted where desired.

PHOTRONIC ILLUMINATION METERS

The standard instruments for plant illumination level tests. Also special high-sensitivity instruments for photo-metric research; and Photronic controllers for turning lights on and off at predetermined levels.

TO MEET EACH MEASUREMENT NEED *Exactly!*

Whether the need arises in the field of industrial research, modern production or maintenance testing, or in other specialized fields . . . it will pay you to check with WESTON. For with a complete coverage of all the types, sizes, ranges and operating specifications, WESTON is in a position to supply an instrument *exactly* suited to your measurement need. Moreover, the fundamentals of *precision* and *dependability* add further justification for making any selection "WESTON". Further details will be gladly furnished upon request. Weston Electrical Instrument Corporation, 591 Frelinghuysen Ave., Newark, N. J.

WESTON *Instruments*

ULTRA SENSITIVE INSTRUMENTS

Double pivoted type, for measurement of minute currents in radio, electro chemistry, etc. Available in single or multi-ranges as DC Millivoltmeters and Microammeters . . . and DC or Thermo Milliammeters, Ammeters and Voltmeters.

MULTI-PURPOSE INSTRUMENTS

Available as Volt-Ohmmeters, Volt-Ohm-Ammeters, and other combinations, including radio tube checking. Ideal for use in production assembly and inspection. Also available in pocket-size, multi-range instruments.

AC CLAMP-AMMETER

A time-saver in maintenance work. Current reading obtained simply by placing clamping jaws around conductor. Circuits never disturbed. 6 current ranges. High insulation for complete protection.

PANEL AND SWITCHBOARD INSTRUMENTS

Available in round, rectangular and fan shapes; in various sizes to meet all requirements from large switchboards to small control panels . . . as well as for all "built-in" needs.

"Must" Instruments to check those condensers

● You owe it to yourself to apply the quality yardstick to condensers you use—especially if in quantities. Also, to save time, trouble, expense, you need the best means of checking condensers, inductances and radio-frequency circuits under conditions simulating actual use. Hence these two suggestions:

● AEROVOX Bridge is popular-priced instrument originally intended for servicemen but now found in many labs. and plants. Costs only $35.75, yet incorporates high-grade meter in place of usual neon-lamp indicator.

Invaluable for checking capacity, power factor, insulation resistance, leakage, etc. of condensers. Also checks resistances.

Because of high-grade meter and variable power supply, externally available, this bridge serves a lot of functions beyond the usual bridge, such as power supply, vacuum-tube voltmeter, voltmeter, millivoltmeter, milliammeter, etc.

No lab. is complete without a bridge. This one is sufficiently accurate for most of the work of condenser users.

● L-C Checker does many important things, yet costs only $29.50 net.

Most attractive feature is way it checks condensers right in their circuits—without disconnecting or unsoldering—at operative radio frequencies. It's a real *radio* test—and a time saver. Checks for capacity, opens, shorts, intermittents. Also checks inductances, circuits, frequency resonant points, etc.

Tremendous help in aligning r.f. and i.f. stages; tuning traps; checking chokes; checking natural period of antennae and r.f. transmission lines, etc.

Truly the "miracle" radio test instrument and indispensable regardless of its low price.

See them . . .

● Your local AEROVOX jobber can show you both instruments. Ask to see them. Ask for data. Or write us direct.

AEROVOX CORPORATION
NEW BEDFORD, MASS.
IN CANADA: AEROVOX CANADA, Limited Hamilton, Ont.

Instruments

THE MAGAZINE OF MEASUREMENT and CONTROL

Vol. 12 No. 12

DECEMBER 1939

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Straws In The Wind

A FEW days ago we re-read Part One of last January's issue of *Instruments* with a definite purpose: to try, after a nearly-fatal illness which made us "lose the page," to grasp in full "What Instruments Do for American Industry." (That was the January theme, you remember, and there were seventeen articles—a general one by National Research Project engineers, the others by authorities in specific fields.) We re-read with a fresh mind all these articles which we had edited eleven months ago. We achieved our purpose only partly—because it would take a colossal intelligence to grasp the entire picture in all its details and evaluate all the benefits of Instrumentation in all the leading industries.

Dig out *your* own copy and re-read it: you will find these "what instruments do" articles as valuable as if written a week ago!

In addition to serving as a memory-refreshing course, the study of these 18-week-old articles, in conjunction with recent contacts, brought out the rapid progress being made at the present time by every instrument-using industry: certain specifically descriptive statements would no doubt be revised by their authors in the light of tremendous advance made in the last few months. You may confirm this for yourself by re-reading the particular article reporting what instruments do in your own industry; here and there, where the author says that something is being done, you will no doubt say to yourself that it has been done.

The underlying causes—inventories, legislation, war, etc.—are difficult to analyze. It is safe to assert, however, that the immediate cause is a keener interest in measurement and control on the part of executives, technicians, engineering professors, economists, technical societies—even government officials. For example, in his article on the textile industry in last January's issue, H. F. Perkins, of the Pacific Mills, had mentioned the textile schools, but who would have thought a year ago that Massachusetts would inaugurate a textile instrument course? Well, here it is:

MASSACHUSETTS DEPARTMENT OF EDUCATION
DIVISION OF UNIVERSITY EXTENSION

Two Massachusetts University Extension courses, "Rayon and Synthetic Fibers" and "Instruments for Consumer and Industrial Testing," will be offered by the State Department of Education during the coming winter months. Both courses will be given by Erwin J. Saxl, Consulting Physicist and Chemist, on Tuesday evenings, starting January 23, at the Massachusetts Institute of Technology, Building 1, 77 Massachusetts Ave., Cambridge. . . .

The course on "Instruments for Consumer and Industrial Testing," meets at 6:30 p.m. and will offer instruction in the methods of determining the value of materials purchased, whether raw products for industry, such as wires, textiles and rubber, or consumer goods such as textile materials and finished rubber products. It will also present the data necessary for a scientific basis of comparison of different products, materials, and claims, and will discuss methods of standardization and recording by the aid of testing instruments in industrial production, purchasing and selling. Actual testing instruments in action will be demonstrated.

Information concerning these courses may be obtained by writing James A. Moyer, Director, Division of University Extension, State Education Building, Newbury and Exeter Streets, Boston.

As to scientific, engineering, and other organizations, a significant recent event is the spontaneous formation of the American Society for Measurement and Control by young instrument men employed in various industries. When we say "spontaneous" we mean just that: this society came into being without stimulation by instrument-makers; and we were not aware of its existence until its president wrote us last July. Among other organized activities, the success of the Temperature Symposium in New York Nov. 2 to 4 was largely due to a growing general instrument-mindedness, as witness the following account:

The Symposium on Temperature, its Measurement and Control in Science and Industry, held by the American Institute of Physics in cooperation with the National Bureau of Standards, National Research Council and a large group of Engineering Societies in New York on Nov. 2, 3 and 4th, was very successful and well attended. The registration was approximately 600 and included engineers and scientists from all over the country. The symposium was held in 19 sessions including a general session at which Dr. John T. Tate, Chairman of the Institute welcomed the assembly and at which Dr. Lyman J. Briggs, Director of the National Bureau of Standards presided. At this general session a paper of special interest to industrial engineers was presented by E. O. Sordahl of the U. S. Steel Corporation on "The Pyrometry of Liquid Steel in the Open Hearth Furnace."

Of the 127 papers presented, a large fraction dealt with the application of physics in industry, principally in the oil industry and the high-temperature industries. Another large group of papers included theoretical topics in general science, precision thermometry, automatic control and instruments. The universal interest in temperature was strikingly shown in this symposium in which there were three sessions on medical and biological subjects, including a paper on the "Temperature of the Human Body in Health and Disease" by Dr. Eugene F. DuBois, a nationally-known authority on metabolism.

The symposium papers will be published in book form, probably in two volumes, within a few months. They will constitute the most comprehensive text on temperature since the pyrometry symposium of twenty years ago.

C. O. Fairchild, Chairman
Advisory Committee

The Counter Reads
0 0 1 4 4
and thereby registers the end of the twelfth year of *Instruments'* service to users of measurement and control devices—to all of whom we wish a Merry Christmas and a
HAPPY NEW YEAR

As to technical societies, it is significant that the American Society for Metals bestowed its Sauveur Award this year on Stanley P. Rockwell, inventor of hardness testing and dilatometric instruments. In fact, nearly all engineering societies are expanding their activities related to instruments. For example, here is a brief report on the annual meeting of the A.S.M.E. last week, received just as we go to press:

At the ASME Annual meeting in Philadelphia, Dec. 4-8, there were presented the following papers of interest to the readers of *Instruments*.

1. "The Principles of Instrument Design" by C. S. Draper of M.I.T. and Geo. Bentley of the Waltham Watch Co., which continues the recent paper in *Instruments* by Draper and Schlestett on "General Principles of Instrument Analysis" and is particularly useful for the design of simple instruments of the "engine indicator" type;

2. "Automatic Control in the Process Industries" by Mason and Philbrick of The Foxboro Co., which gives a mathematical treatment of a complete controlled system, useful to anyone working in this field; and

3. "Thermostatic Bimetals" by Eskin and Fritze which has an interesting treatment of the hysteresis due to the "two-phase" nature of invar.

The first paper was sponsored by the Machine Design group and the others by the Committee on Industrial Instruments and Regulators which also had an interesting report by a subgroup on terminology.

Ed. S. Smith, Jr., Chairman
Committee on Industrial Instruments and Regulators

And so it goes! Let philosophers and economists figure out recondite primary causes. As for us, we see straws in the wind; and the beneficial wind is a growing instrument-mindedness among Americans who work productively, think logically and act constructively.

—M. F. Behar, *Editor*

THE MONTH'S NEW INSTRUMENTS

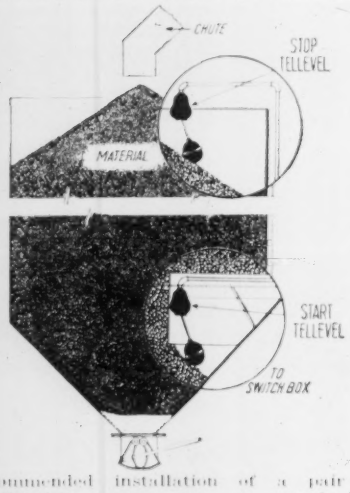
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Liquid or Granular Material Level Control Switch

"Tellevel Automatic Storage Control" is a dust-tight explosion-proof multiple-electrode mercury switch so mounted that tipping it breaks the circuit. Illustration shows



recommended installation of a pair of "Tellevels"—one to start conveyor feeding material into bin; the other to stop conveyor when bin is full.—*Stephens-Adamson Mfg. Co., Aurora, Ill.*

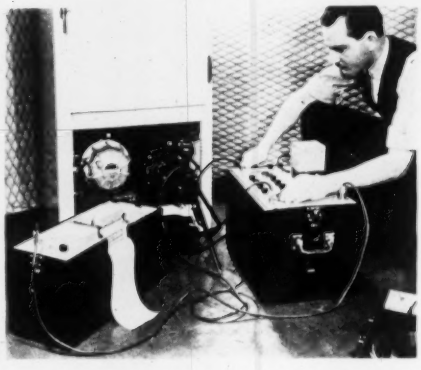
Repeat Cycle Timer

New repeat cycle timer is designed for use on a-c. circuits to (a) alternately close and open one or two circuits continuously at any preset operating interval, (b) close

or open a single circuit after any preset operating interval and stop, ready to repeat upon reclosure of a starting switch. Available in time ranges (different dial scales) from 1 min. to 12 hrs. total. Each dial is equipped with a frictionally-held operating arm adjustable to any desired operating cycle within dial range. Motor, ratings and other features are similar to those of same maker's Cycle Controller described in last month's issue, page 286.—*E. W. Cramer, Inc., Centerbrook, Conn.*

Audio-frequency Spectrum Recorder

Announced as an "industrial stethoscope" for the use of acoustic engineers engaged in diagnosis and checking of running machinery, new Recording Frequency Analyzer achieves frequency analysis by the



sweep method, using a small drive motor to actuate the frequency dial which sweeps the whole range of audible frequencies (from 30 to 10,000 c.p.s.). With this motor is synchronized another motor driving a strip chart on which a stylus traces the sound level at each frequency passed. Sharpness of frequency selection is assured by crystal filters said to be "the finest available."—*Electrical Research Products Inc., 195 Broadway, New York City.*

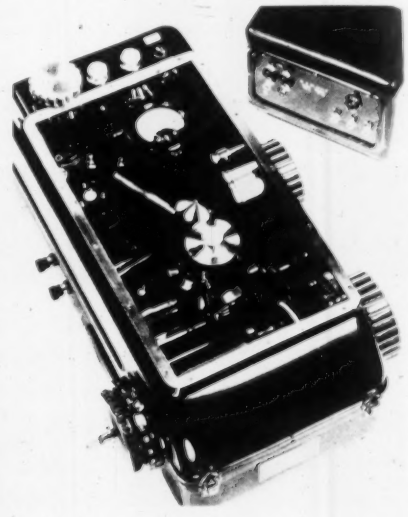
Test Gage

New Laboratory Test Gage, for checking pressure gages, is announced. Its accuracy is guaranteed to within 0.25% of scale range. Outer edge of dial is a mirror, to

prevent parallax error. Gage has a transparent plastic cover (see *Instruments*, Nov. 1939, page 288.) Case is Phenol.—*Ashcroft American Gauge Div., Manning, Maxwell & Moore, Inc., Bridgeport, Conn.*

Chemical Analysis Recorder Using Heyrovsky Method

Heyrovsky Micro Polarograph is announced for polarographic analysis, a new analytical method based on current-voltage curves and relying principally on the dropping-mercury cathode to provide a completely polarized electrode in conjunction with one which is not polarizable. Applica-



tion of the dropping-mercury cathode is said to have been perfected to a point that, when employed with an adequately specialized measuring system, it offers the following analytically significant characteristics: (1) a completely polarized cathode; (2) a non-polarizable anode; (3) a high hydrogen overvoltage at the cathode; (4) a continuously renewed cathode surface; (5) an automatic, continuous resolution of deposited substance; (6) a minute cathode area, at which diffusion rate can be established as a current limit. Primary functions of Micro Polarograph are (1) to apply to the electrolytic cell at a predetermined uniform rate an accurately known voltage change and (2) to indicate and record precisely the current flowing through the cell at all stages of voltage increment. The resulting polarogram is two-dimensional with applied voltage measured along the abscissa and current or linear galvanometer deflection measured along the ordinate. When a point has been reached equal to the reduction potential of the available ion a rapid acceleration of current begins which, in turn, leads to a deceleration ending in a slope roughly corresponding with that of the initial section. The characteristic form of that part of a polarogram which shows the identity and concentration of the discharging ion is called a current step. The position with respect to the voltage axis at which the sharp acceleration takes place, indicates the reduction potential of that ion under the conditions existing in the electrolyte and with respect to the mercury cathode. This voltage, called the half-wave potential, is a characteristic constant for each ion, independent of the concentration of that ion. Under proper operating conditions, height of step is proportional to the existing concentration of the substance yielding the discharging ion. Limit for qualitative detection and identification in polarographic analysis is of the order of 0.01 gamma of mass, or one hundred-millionth of a gram. For quantitative measurement, maximum convenient dilution is about 10^{-5} to 10^{-6} N.—*E. H. Sargent & Co., 155 East Superior St., Chicago, Ill.*

BAILEY METER
CONTROL SYSTEM

The Mark of

Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

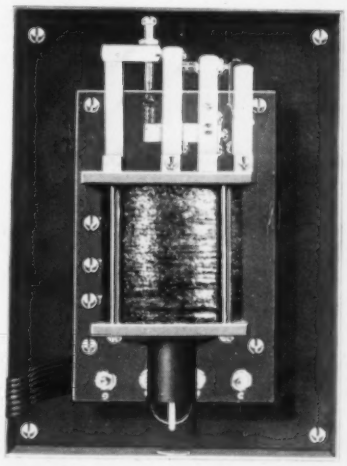
G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Automatic Voltage Regulator

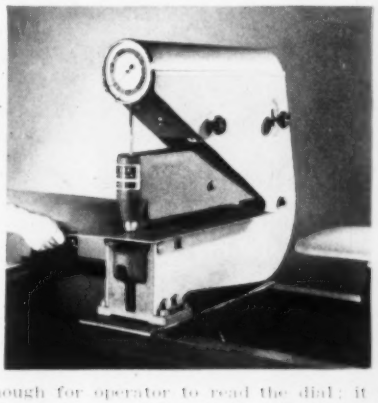
New "GB-1" voltage regulator is for small alternators of the separately-excited type whose exciter field currents do not exceed 1 amp. at maximum load on alterna-



tor. Operation: Alternator voltage is imposed across the regulator coil (and series voltage dropping resistor which decreases voltage error due to frequency changes). Current through coil acts to "pull floating iron core upward, opening contacts. When closed, contacts short out exciter field rheostat; when open, they allow full resistance in exciter field circuit. When alternator voltage is normal, contacts are in a position to alternately cut exciter field rheostat into and out of the circuit, the a-c. voltage being determined by average resistance, or ratio of time contacts are closed to time they are opened. Contacts open and close 120 times per second. Regulator response to a given load change is, therefore, ½ cycle, or 1/120 second. Stationary contact is mounted on a light leaf spring, which absorbs rapid vibration of moving contact and eliminates "clinging" or "bouncing." Adjustments of a-c. voltage, by an adjusting screw; of sensitivity and stability, by tension screw at base of stationary contact post (this adjustment is extremely sensitive).—*Burlington Instrument Corp., Burlington, Iowa.*

Sheet-gaging Micrometer

"Guyer Gauger" is a mechanical micrometer for rapidly checking thickness of metal sheets. In operation it clamps a sheet at any point; work is held at this point long



enough for operator to read the dial; it is then automatically released for removal from machine or to next point to be measured. Cycle of clamping, gaging and releasing is constantly repeated. Cycle frequency is under control of operator. Standard machine will indicate from 8 to 38 gage reading per minute; others can be supplied. Throat of machine is 23" deep clear of measuring anvil. Dial is graduated in 0.001" increments.—*Streeter-Amet Co., 4101 Ravenswood Ave., Chicago, Ill.*

New

PUSH-PULL ELECTRONIC VOLTMETER-OHMMETER

.05-5000 Volts DC in 9 Ranges!
.01 Ohm-1000 Megohms in 7 Ranges!

IT'S THE *Rider Volt Ohmyst!*

HERE'S a laboratory instrument with ranges so wide it will not only take care of today's engineering requirements—but tomorrow's as well.

It's the Rider Volt Ohmyst and with it you can measure DC voltages in high resistance photo-cell circuits, television circuits, bias cells, operating voltages across tuned circuits with the signal present—with surprising speed and accuracy. This instrument covers the actual operating voltage. No circuit loading. Its input resistance of 160,000,000 ohms on all ranges between 500 volts and 5000 volts makes the Rider Volt-Ohmyst a universal instrument—one that has minimized obsolescence. Get full details and specifications from your RCA Test Equipment Distributor—or write to the address below.

The Rider Volt Ohmyst is Stock No. 168—**net price $57.50.**

Over 335 million RCA radio tubes have been purchased by radio users . . . in tubes, as in Parts and Test Equipment, it pays to go RCA All the Way.

RCA *Test Equipment*

RCA Manufacturing Co., Inc., Camden, N. J.
A Service of the Radio Corporation of America

Street Lighting Evaluator

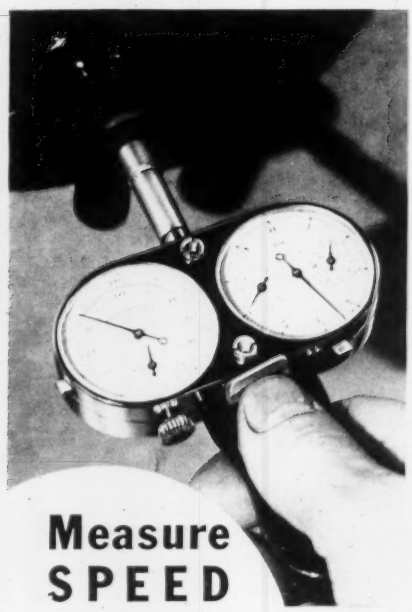
New "G-E Street Lighting Evaluator" serves as a traveling laboratory enabling safety authorities to quickly, conveniently, and accurately evaluate the effectiveness of

street lighting systems. It comprises three essential parts. One, mounted on hood of automobile and extending beyond radiator, is a miniature strip of street, with pavement similar in tone and texture to surface of roadway under study. On it are typical obstacles. Its position above headlamps of approaching cars makes it possible for investigator to proceed with an appraisal at any time without waiting until traffic has disappeared. Part resembling a loud speaker above windshield is a glare collector which measures total glare from all street lamps, within driver's field of view, and loss of vision resulting therefrom. On driver's seat is operator's control box provided with dials and selector switches. It automatically records on a card the measurements of the three factors—brightness of pavement, objects, and interference with seeing caused by glare from the system. Only a few moments are said to be required for operator to compute the net visibility at a given location.—*General Electric Co., Lamp Dept., Nela Park, Cleveland, Ohio.*

Tube Tester

New "Model 3111" tube tester occupies bench or counter space 10"x15" and is 7" high, overall. Controls are mounted on sloping panel. 4½" scale is calibrated in four

multi-colored ranges. Test circuits are in accord with latest RMA standards with 25-watt line control and special 6H6 circuit to insure accuracy. Test features include provision for "hot" interelement short and leakage tests; checks of cold-cathode rectifiers; testing individual sections and elements of multi-purpose tubes, duo-diodes and full-wave rectifiers; full floating filament tests with any voltage available at any two prongs of all sockets, etc. Direct-reading ohmmeter (power supply self-contained) provides ranges of 0-10,000 and 0-1 megohm. Direct-reading capacity ranges are 0.001-0.1 and 0.1-16 mfd. Neon indicator provides condenser leakage tests. Also available (Model 3111') as a combination portable and counter unit.—*Radio City Products Co., 88 Park Place, New York City.*



Measure SPEED

with split-second accuracy

The *"Jagabi" Hand Tachoscope* gives you the exact number of revolutions in the exact time in which they were made. An automatically combined speed counter and stop-watch, for all speeds up to 20,000 rpm.

Send for Bulletin 1505-I.

JAMES G. BIDDLE CO.
Electrical Instruments
1211-13 Arch Street Philadelphia, Pa.

FOR ALL SCIENTIFIC USES

•GUINAND
•GALLET...
•GALCO & SECURITY

TIMERS

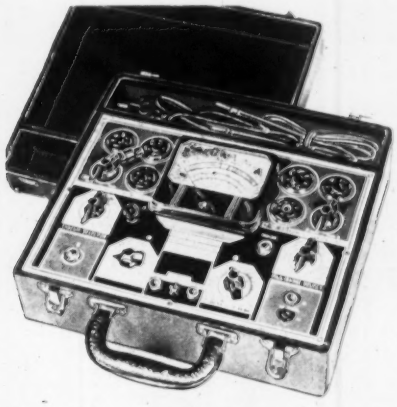
Recognized by experts as the best in the stop watch field

FREE Catalog on request

JULES RACINE & CO.
20 WEST 47th ST., NEW YORK

Multiple Service Instrument

New, "Model 801" combines functions of a tube tester, set tester and "multi-meter." With its power supply, it is built into a carrying case 12" × 12½" × 6". It has a d'Arsonval movement with "Alnico" magnet



and multiple scales in three colors. Accuracy is 2%, voltage sensitivity 1000 ohms-per-volt. A-c. voltages are read on linear scales. All old and new tubes can be tested at standard RMA voltages and loads and with filament or heater voltages available up to the full line value. Line voltage is controllable from 103 to 135 volts and provision is made for "hot" interelement short and leakage tests, testing individual sections of multi-purpose tubes, noise tests, etc. Ranges: D-c. voltmeter, 0-10/50/500-1000; a-c. voltmeter, 0-10/50/500-1000; d-c. milliammeter, 0-1/10/100-1000; d-c. ammeter, 0-10; ohmmeter, 0-500/5000/1 meg, 10 megs.; db meter, —8 to +15/45-29/29-49-32-55; output, same as a-c. volts. Tester is available in two types, for 115-v. a-c., and for 220 v. a-c. lines.—*Radio City Products Co., Inc., 88 Park Place, New York City.*

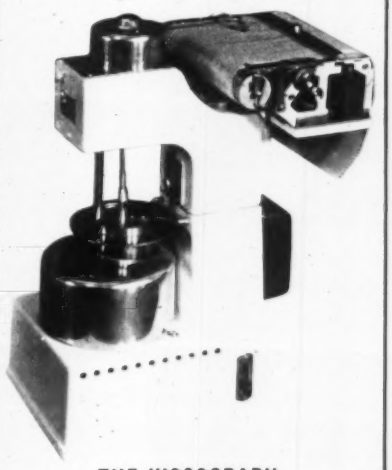
Portable Drawing Table

"Handy" portable folding drawing table does not shake when in use, sets almost automatically to the right drawing position, has a pencil and instrument rack

across the top, folds to 3" thick. The 20" × 26" pine drawing board is permanently attached to a hardwood supporting frame.—*Eugene Dietzgen Co., 2425 Sheffield Ave., Chicago, Ill.*

RECORDING VISCOSITY

With Automatic Constant Speed Temperature Increase



THE VISCOGRAPH

Recording Viscosimeter, with the following novel features:

1—Automatic constant speed temperature increase—from room temperature to 150° C.

2—Constant temperature, adjustable to any point within the above range.

The Viscosity is recorded continuously by means of a curve.

The VISCOGRAPH has been applied successfully in the testing of:

Oil	Glue	Artificial Silk
Printing Ink	Detrin	Starch
Latex		Flour, etc.

BRABENDER CORPORATION

ROCHELLE PARK, N. J.

RUBICON PORTABLE PRECISION POTENTIOMETER

Available in a number of double range combinations, such as 1 volt and .1 volt, 100 MV and 10 MV, also in pH ranges. Guaranteed accuracy .1%. An outstanding value.

Described in Bulletin 270, which also describes *Rubicon* High Precision Type B Laboratory Potentiometer.

We also make galvanometers, electrometers, colorimeters, permeameters, Wheatstone and Kelvin Bridges, Resistance standards, coil testers, acronographs, clip-on transformer ammeters.

Descriptive bulletins available on request.

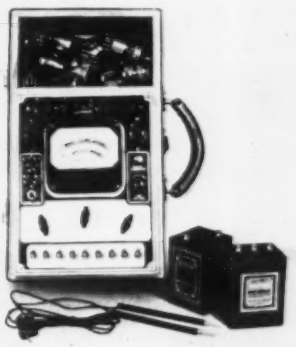
RUBICON COMPANY

Electrical Instrument Makers

29 North 6th Street Philadelphia, Pa.

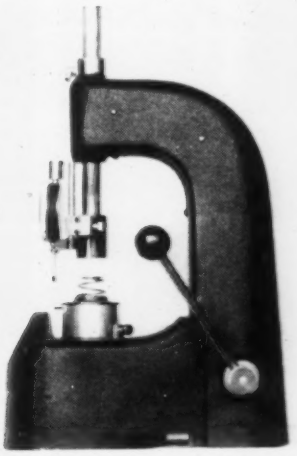
Tube and Battery Tester

New "Model 777" Tube and Battery Tester is said to be the first tube checker permitting battery tests under the correct load, so that if battery shows "good" on instrument scale, it will be capable of delivering sufficient potential to receiver when loaded with all of tubes. Condition of battery is indicated on a "good-replace" scale. Current drain on battery is also adjusted to conform to requirements of set. Model 777 tester is available both in counter and portable types, the former having a new roller index system, also noise test and complete inter-electrode short check. Battery test and tube test measurements are made on separate scales.—*Weston Electrical Instrument Corp., 581 Frelinghuysen Ave., Newark, N. J.*

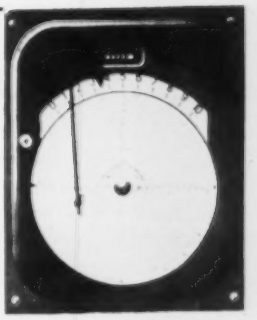


Spring Checker

Available in 10-, 50- and 250-lb. capacity units, new "Model PB3 STP" is furnished standard with a 6" vertical height scale graduated to 1/32" for indication of compressed height. Shown here equipped with a special 1" travel reverse-reading dial indicator fitted in an adjustable ram bracket to allow maximum range of 1". For quantity work there is available the "Height-rol," an electrical contact circuit giving a buzzer signal when preset height stylus makes contact. For checking small tension springs, a bridge may be fitted to the table. Typical applications include checking springs for load at one or more compressed heights; testing fixture where load reading of pressure or compression is required; testing rack-and-pin or assemblies and assembly of firing pin mechanisms are examples. Accuracy is said to be well within ASTM standards for this classification of testing equipment. Units are equipped with precision ball bearing throughout. Height of machine, 19"; base 8"x14"; weight approx. 50 lbs.—*Link Engineering & Mfg. Co., 1654 W. Baltimore Ave., Detroit, Mich.*



How COCHRANE METERS save fuel costs for SLOANE-BLABON



Cochrane Flow Meters at the Sloane Blabon Corp. of Philadelphia, have fully justified the title of "Cash Register of the Coal Pile."

Cochrane Electric Flow Meters are used as one means of checking the efficiencies of various types of coal and have enabled Sloane-Blabon to select a coal that has resulted in an annual steam cost of only 16.78 cents per 1,000 lbs., including handling to the stoker hopper. The two bottom meters measure steam output from two 50,000 lbs. hr. boilers and the top meter measures the pressure of steam and pressure and temperature of the feed water.

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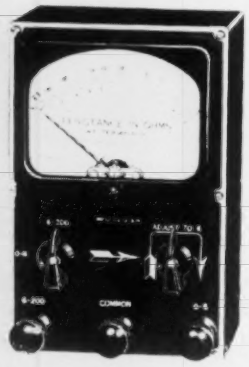
Ultra-low-range Ohmmeter

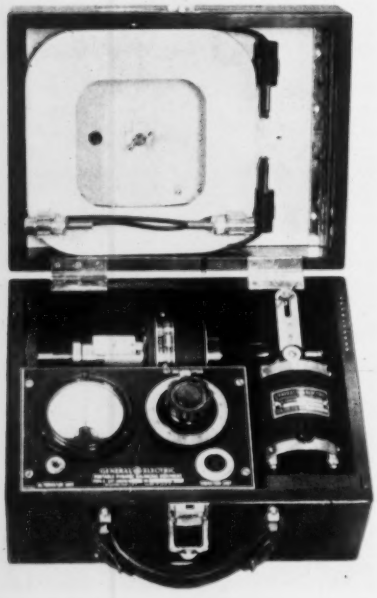
New "Model 1975-S Ultra-low-range Ohmmeter has a 3½" long scale said to give highly accurate measurements at low values of resistance on two ranges, 0-6 and 6-600



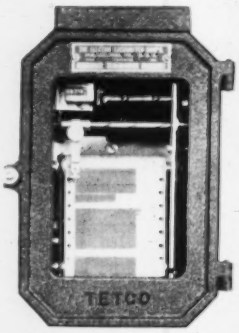
ohms, because of the non-overlapping of the two ranges, thus permitting battery adjustment at the logarithmic center of the accurate section of the scale. Overall accuracy is approx. ± 1% of scale deflection, the scale extending over 100°. Instrument is self-contained, utilizing three easily replaceable flashlight cells, connected in parallel to prevent frequent replacement. Change in battery voltage does not affect accuracy. Special low-resistance leads of No. 8 stranded, rubber-insulated wire have large surface clips at each end. *The Hickok Electrical Instrument Co., 10527 Dupont Ave., Cleveland, Ohio.*

Portable Dynamic Balancing Equipment

New portable dynamic balancing equipment, for use wherever rotating masses require balancing to eliminate vibration, is capable of measuring amount and phase angle of unbalance vibration present in bearing pedestals of a rotating machine running in its own or substitute bearings at any speed between about 600 and 5000 r.p.m. The balance being made under operating conditions, changes effected by load and by the foundations are included. Trial runs required in balancing auxiliary equipment in central stations and manufacturing plants are reduced to a minimum of three. Complete equipment, packed in a single case with no batteries or external power source required, consists of a sine-wave alternator, a vibration pickup, and an instrument with its associated circuit on which nils displacement of the vibration are read. Sine wave alternator spindle is inserted in lathe center hole in either end of rotor machine to be balanced; vibration pick is placed against rotor bearing. Determination is made with the machine in its original condition and also with two trial weights attached. Then, from these measurements, calculations are made on a form sheet to determine final weights and the location to be applied to correct original unbalance. *General Electric Co., Schenectady, N. Y.*



TETCO
Speed Recorder



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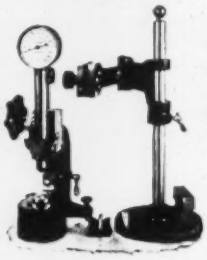

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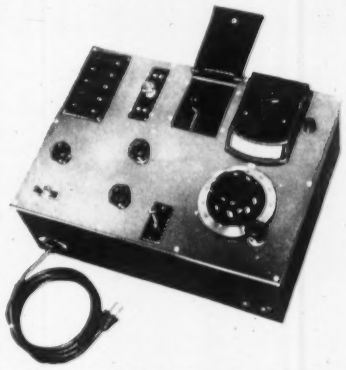
Photoelectric Colorimeter

New "Lumetron Colorimeter" has been designed for greatest possible flexibility and for obtaining results reproducible within narrowest possible limits. Its construction allows use of a great variety of sample holders and light filters, including monochromatic filters. Applications range from simple measurements of light transmission



of liquids to colorimetric and turbidimetric chemical analysis and to abridged spectrophotometric determinations. Special provisions have been made for accurate measurement of extremely dark and extremely transparent liquids, it is said. Instrument uses two blocking-layer photocells in a balanced circuit, operates from power line without constant-voltage transformers. Line voltage changes do not affect readings. Four standard models: (1) For general purposes, a self-contained unit with built-in pointer galvanometer, suited for broad-band color filters and for 1" plane parallel sample holders or test tubes or microcells. (2) For abridged spectrophotometric analysis, equipped with an especially powerful light source and a highly sensitive mirror galvanometer to allow use of monochromatic filters which are inherently dark. (3) To accommodate sample holders up to 6" long for accurate measurement of almost colorless liquids. (4) Combining monochromatic feature and long sample holder. Light from a concentrated-filament bulb is condensed to form a parallel beam which passes at right angles through the plane parallel sample holder so as to avoid errors due to differences in refraction of liquids. Holder for standard 2" × 2" filters is so arranged that the same filter serves both photocells. Intensity of the lamp can be controlled; also, by operating a key switch, circuit is changed so that intensity of light incident on cell is read on galvanometer; thus it is possible to allow not only for changes in light output of lamp but also for light absorption of filter used in each case. In order to obtain linear response, cells are connected in a zero-potential circuit. To reduce influence of thermal effects on photocells, models having powerful lamps are provided with forced-draft ventilation. For protection against overload, galvanometer is equipped with a protective resistor; when instrument is near balance, resistor is cut out by key switch and full sensitivity of galvanometer is used for final adjustment. Another protective feature: lamp turned off automatically when filter holder is removed. Special models can be furnished with built-in range switches to spread dial readings over any desired limited transmission range. *Dr. F. Lawcenberg, 10 East 40th St., New York City.*

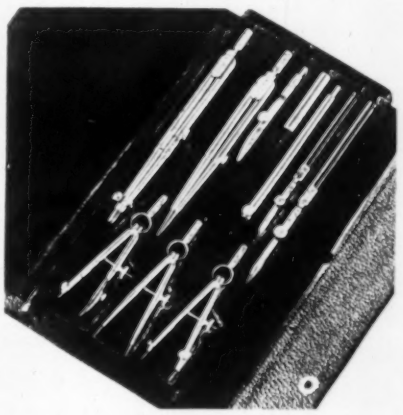
Radio Compass for Yachts and Coastwise Craft

New "50A" radio compass unit is said to give yachtsmen and others operating coastwise vessels a precision navigating instrument, is designed to operate in con-

junction with maker's marine radio telephones, covers frequencies between 230 and 350 kc, which include U. S. Lighthouse Service and Civil Aeronautics Authority radio beacons. It consists essentially of a specially shielded loop antenna, mounted on a tuned r-f. amplifier, and a frequency converter. It derives all power from the radio telephone equipment with which it is used. It measures 10" wide, 7½" deep, 22¼" high including loop, and weighs approx. 17 lbs. —*Western Electric Co., 195 Broadway, New York City.*

Drawing Instruments

American-made drawing instruments developed for straight-line production and called "Minusa" contraction of "Made in U. S. A." have a slender "rounded taper"



construction, designed to produce balance and maximum strength. Except for the hand fitting of all moving parts, Minusa instruments are made by modern machine production methods said to improve on hand operations.—*Keuffel & Esser Co., Hoboken, N. J.*

A practical Noise Instrument for *Routine Production Testing* in your plant

Industrial Noise Analyzer RA-273

- Simplified controls
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- 38 filter combinations
- Large indicating meter
- Feedback stabilized amplifier
- A. S. A. standard sound meter
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FOR THE PLANT—Large number of filter combinations permits segregation of different noises characteristic of specific defects in assembly. Simple controls adaptable to production line conditions. Rugged design insures calibration stability and reliability.

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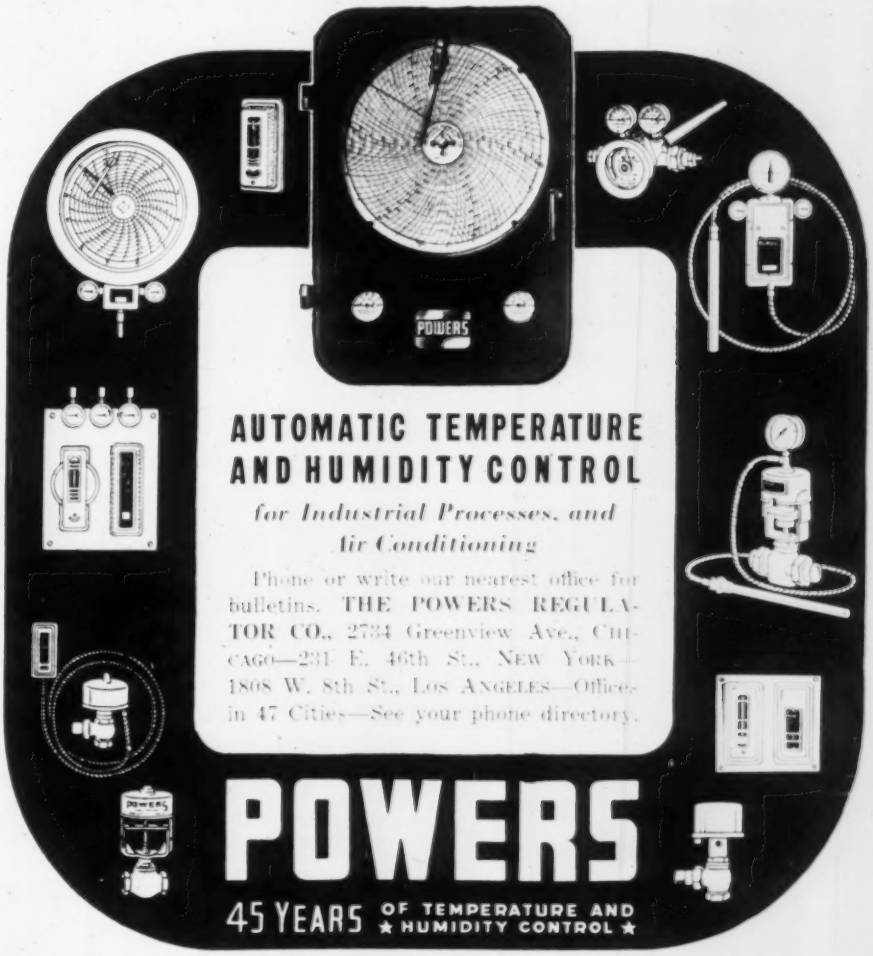
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Laboratory C-r Oscillographs

Recent advances in cathode-ray oscillography are said to be incorporated in new "Type 175" for study of high- and low-frequency recurrent phenomena, and "Type

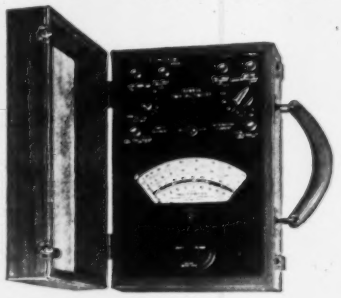
175-A" in which control circuits have been added to the saw-tooth oscillator, permitting single-sweep control of the horizontal deflection. Both employ "Type 54-11-T" 5" intensifier-type c-r. tube fully described in March 1939 *Instruments*, page 76. High-gain wide-frequency-range amplifiers for both horizontal and vertical axes, permit instrument to be used directly from output of vibration pickup units or with proper microphone, have response uniform within better than 10% from 5 to 100,000 sinusoidal cycles per second. To facilitate study of phase relationships, horizontal and vertical amplifiers are identical so that any phase delay thereby introduced is identical in both axes. Push-pull deflection-amplifier stages, provide symmetric deflection of c-r. tube, obviate spot defocusing at extreme edges of screen. A new feedback circuit for supplying signal to grid of second tube of push-pull deflection stage of each amplifier is so arranged that pattern shifts due to short-time power-supply voltage fluctuations are balanced out and pattern remains steady on screen. Sweep circuit provides essentially linear horizontal deflection as a function of time, reads time from left to right, is continuously variable over a repetition rate from 15 to >30,000 times per second. In "175-A", there is also included a sweep circuit so controlled that beam remains at one side of screen until initiating impulse is received, at which time the beam makes only one complete linear sweep.—*Allen B. DuMont Labs., Inc., 2 Main Ave., Passaic, N. J.*

Delayed-action Mercury Switch

New "Kon-nec-tor" mercury switch units are announced, in which mercury is caused

to flow through orifice, thereby causing predetermined delay. Sizes, etc., correspond to "Kon-nec-tor" line; delay intervals from 0.5 sec. to 10 sec., for circuit-closing or -opening.—*General Electric Co., Schenectady, N. Y.*

Rawson Twin Multimeter



29 ranges in less space than any near equivalent combination—size 12" x 8" x 6"

RANGE OF MEASUREMENTS

D.C. 1 microampere to 1 ampere
20 microvolts to 1000 volts
A.C. cup to 5000 cycles
2 milliamperes to 2 amperes
60 millivolts to 1000 volts

Special apparatus built to order

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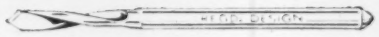

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from .0016 up to .1969 inch diameter, all sorts of small turned parts. Small wood screws in brass, steel, etc., turned from the bar.

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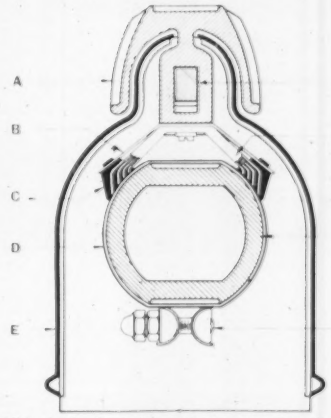
Rheostats With Lubricated Individually-fitted Brushes

An entirely new line of sliding-contact rheostats, for plant and laboratory applications, is said to incorporate a number of improved features never found before in



A—Slider knob. B—Lubricator pressure spring. C—Graphite lubricator. D—Resistance winding. E—Perforated metal housing. F—Slider bar. G—Laminated metal contact brush. H—Porcelain tube. I—End band tie.

commercially-available rheostats. Graphite lubrication, originated by manufacturer, is accomplished by a pair of graphite blocks, each held in the path of the brush by a separate spring. This not only eliminates wear and gives easy action but prevents fusing of sliding member to winding—a trouble often caused by overloading. Each brush has eight separate contacts, is of laminated spring-tempered phosphor bronze, ground by hand and fitted to each rheostat. Brushes have a small and constant intermediate resistance; with minimal load of each of the eight segments to assure retention of resiliency after heavy overloading. Winding is a Cu-Ni alloy with negligibly small temperature coefficient of ohmic resistance; its form is close-wound oxidized wire, or space-wound ribbon, depending on current capacity. Porcelain tube is glazed inside and out. It has two longitudinal recesses, bridged by the windings, whereby windings dissipate heat faster than they would on a plain cylinder, and are also held more tightly in position—two characteristics useful in case of overloads. Slide bar is not only extremely rigid but is prevented from turning by means of ceramic bushings. More than 100 sizes and ratings are available in the conventional (open) form; also more than 100 with complete protection, as illustrated, which makes it impossible for use to touch either a "live" or a heated part.—*Rex Rheostat Co., 37 West 20th St., New York City.*

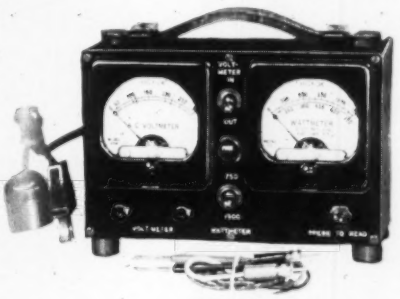
Cast Metal Specimen Mold

New cast metal mold, used to form test specimens of either non-ferrous or ferrous metals, is made of heat-resistant cast iron, is provided with two steel handles to facili-

tate operation. Metal poured into pouring basin forms four test specimens ½" diam. × 1" long. Two of these may be used for spectroscopic analysis and the other two broken into ½" pieces and weighed for carbon or sulphur determinations. Specimens may be made ready for the laboratory in less than a minute.—*Harry W. Dietert Co., 9330 Roselawn Ave., Detroit, Mich.*

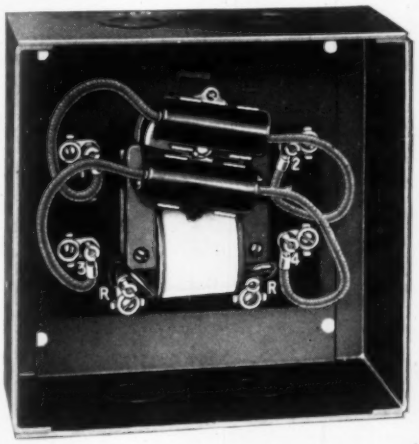
A. & D-c. Appliance Testing Volt-wattmeter

"Model 145" dual-instrument tester checks line voltage while measuring consumption in watts in appliances. Voltage drop through house wires is checked by noting drop in voltmeter reading when appliance is plugged in. Checks starting coils in fractional h-p. single-phase motors. Watts are indicated on two ranges—0-750 and 0-1500. Wattmeter has electrodynamometer movement and a uniform scale—an exclusive feature. Voltmeter range 0-300 with red line at 110 and 220, magnetic vane movement gives practically uniform scale. Both instruments have 2½" scale length. Two sets of leads are supplied. Toggle switch connects voltmeter direct to separate test jacks. Fuse protects all volt circuits. Instruments may be continuously connected to circuit under test. Special carrying case has lead compartments.—*The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.*



High-speed Relay

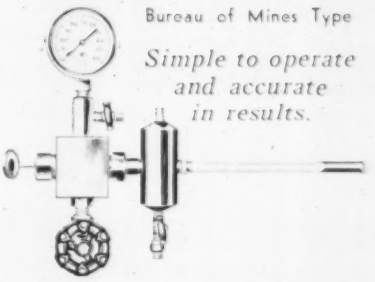
New "M-39" relay is said to be the only rotating type of relay employing a tilting mercury switch, designed for high-speed operation. Magnetic brake damps movement of switch, making it "dead beat." Mercury switch, attached to a rotating disk on armature shaft of magnetic element, is unbreakable. Its refractory breaker shields metal parts from arc, retains a pool of mercury in cup end so that there always is a positive mercury-to-mercury contact, and serves as a "dam" over which mercury separates, thus locating the arc, which is de-ionized and completely shielded. Relay is furnished in two styles: with a single mercury switch and with two switches. Switches are furnished for make or break, or for make-break combinations. At 115 volts a.c. each switch has a breaking capacity of 15 amps. Operating coils from 6 to 250 volts a.c. or d.c. are available and have a current consumption of approx. 5 watts. Mechanism is mounted on a Bakelite panel 3" high and 2¼" wide. It is regularly furnished in a metal cabinet 6" × 6" × 3".—*The Autocall Company, 30 Mack Ave., Shelby, Ohio.*



DEW POINT TESTER
FOR HIGH PRESSURE GASES

Bureau of Mines Type

Simple to operate and accurate in results.



This apparatus for the accurate determination of the dew point of gases under pressure was developed by the Bureau of Mines and is described in its Report of Investigations 3399.

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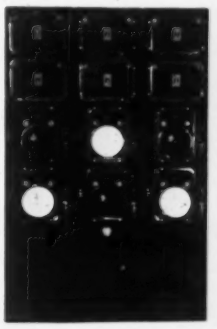

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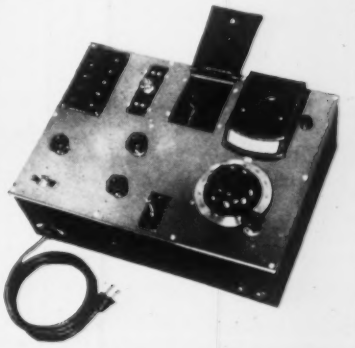

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Barrier-Layer Photocells in a great variety of sizes and shapes. Mounted in various styles of casings or unmounted.

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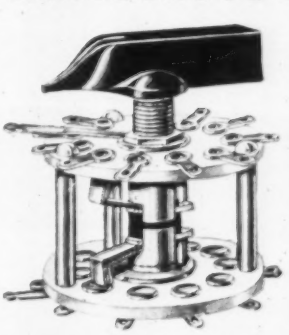
SHALLCROSS SOLID SILVER SWITCHES



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Superior solid silver switches—No. 536—single section and No. 537—two section—1 to 11 contacts of fine solid silver and multi-leaf silver contactarms. Utilizing Ceramic switch plates with high surface leakage; designed to withstand high voltage or maintain extremely low contact resistance. Write today for complete information in Bulletin No. 500 HM.

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Electrical Measuring Instruments and Accurate Resistors
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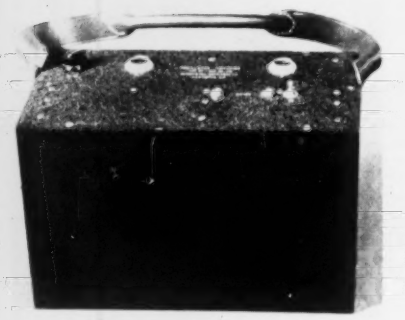
Oscillator-Amplifier

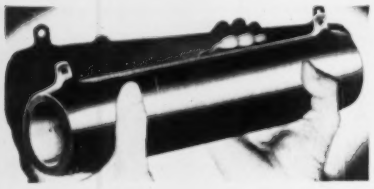
Primarily designed for geophysical work, but suitable also for buried-metal detection, new "No. 160" weighs 26 lbs., measures 13" × 6.4" × 8.3", combines a v-t.



oscillator and a high-gain (adj. to 100,000) amplifier, is regularly available with factory-set audio or radio frequency, also available especially with limited adjustable frequency range. "A" and "B" dry batteries are included and provision is made for connecting external storage battery.—*Geophysical Instrument Co., 4315 Half St., S. E., Washington, D. C.*

500- and 1000-Watt Resistors

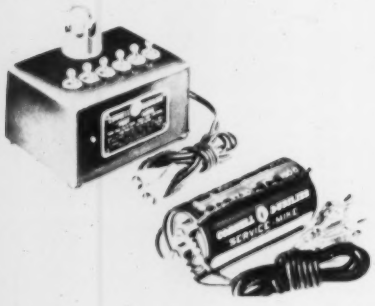
Maker's line of heavy-duty vitreous-enameled resistors has been extended by addition of 500-watt (illustrated) and 1000-



watt units, now numbers more than fifty sizes. Larger units are available also in "Corrib" type with corrugated ribbon winding.—*Ohmite Mfg. Co., 4835 W. Flournoy St., Chicago, Ill.*

Servicing Instruments for Motor-starting Capacitors

New "Test-Mike" is a multiple-capacitor unit of a-c. electrolytic type, with six toggle switches which in different position combinations provide twelve capacity values



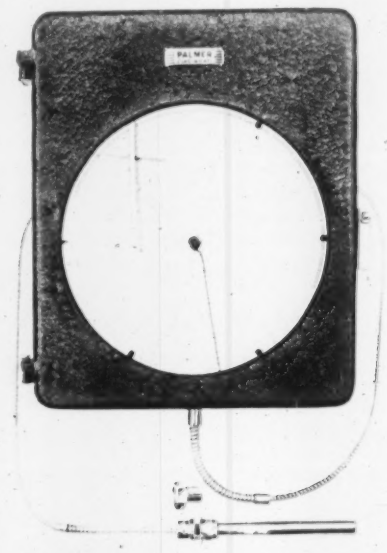
ranging from 18.75 to 150 mfd. It includes a pilot lamp for checking operation of the mechanism which cuts out the starting capacitor when running speed has been reached. Case dimensions 3½" × 5" × 3". New "Service-Mike" gains even greater compactness through elimination of case, switches and pilot lamp; has same capacity range as "Test-Mike" but the twelve variations are obtained through different interconnections of its four terminals. It is cylindrical: 1 13/16" diam. and 3⅞" long.—*Cornell-Dubilier Electric Corp., South Plainfield, N. J.*

Hand Aspirated Psychrometer

New "Type HA/2" is an improved model of hand aspirated psychrometer described in April 1926 *Instruments*, page 93. Thermometers are of 10°-110°F. range with 1° graduations. Handle of instrument forms case and when not in use thermometer and mechanism fold up inside handle, resulting in pocket-size instrument, 7½"×1½"×¾"; weight 8¾ oz.—*Julien P. Friez & Sons, Inc., Baltimore St. & Central Ave., Baltimore, Md.*

Recording Thermometers

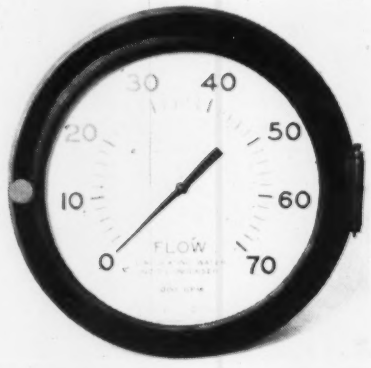
Maker, long specializing in mercury-in-glass industrial thermometers, has brought out a line of mercury-in-steel recording thermometers. Announcement, made after



tests and actual service said to have covered many months, states that "each working part has been designed for maximum strength."—*The Palmer Co., 2541 Norwood Ave., Cincinnati, Norwood, Ohio.*

Round-case Flowmeter

Originally developed for a central power station where available panelboard space limited case diameter to 14½", new round-case model has same internal parts as mak-



er's standard electric flowmeter. Illustration shows flow indicator; also available are recording, integrating and combination models.—*Cochrane Corp., 17th St. below Allegheny Ave., Philadelphia, Pa.*

Actuator for Micro Switches

For use in conjunction with Regular and Metal-Clad Switches, new "Type J" complete roller lever actuator has two mounting holes which register with those of the

Micro Switch. Its lever arm rides on an oilless bronze bearing, which rests on plunger of switch. A case-hardened roller with an oilless bronze bearing is mounted on end of lever arm. Operating ratio is about 8 to 1.—*Micro Switch Corp., Spring St., Freeport, Ill.*

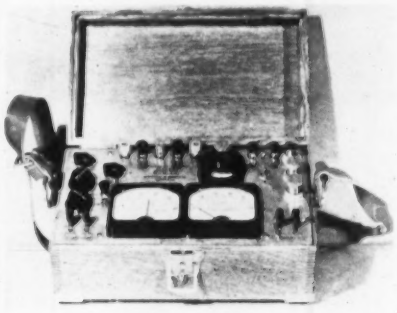
Small Wire-wound Resistors

New and compact "Ohiohm" ceramic-insulated resistance units, for photoelectric safety and counting devices, motor-starters and relays, etc., are announced. Standard

units are from 5 watts to 20 watts; various resistance values; guaranteed accuracy ±5%. Axial terminal wires replace usual projecting side-lugs. Tough porcelain core has large radiating surface on inside and outside. After winding, the wire, of low resistance-temperature coefficient, is covered with baked-on ceramic coating which resists heat, moisture and vibration.—*The Ohio Carbon Co., 12508 Berea Road, Cleveland, Ohio.*

Resistivity Method Prospecting Apparatus

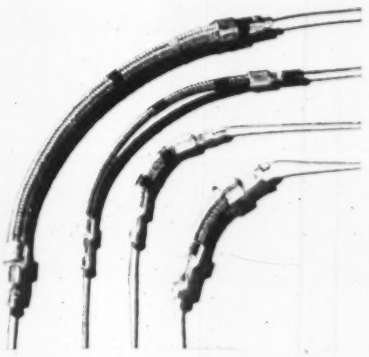
For prospecting and sub-surface investigation by electrical resistivity method, "Type LR" Earth Resistivity Apparatus employs the Wenner four-electrode method.



Currents are read on a 3-range milliammeter, potentials by a mill method. A rugged galvanometer is included but for extreme sensitivity an external galvanometer may be employed. All control and measuring elements are mounted upon a panel which serves also to shield current and potential circuits from each other. Apparatus may be used with maker's Gish-Rooney Commutator for resistivity measurements by means of commutated direct currents (*Instruments*, May 1937, page 128).—*Geophysical Instrument Co., 1315 Half St., S. E., Washington, D. C.*

Fibre-glass Flexible Resistors

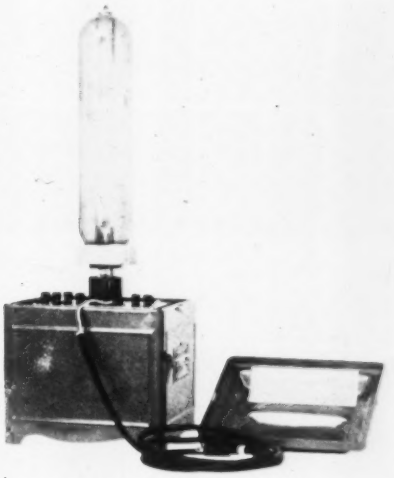
New "Glasohms" make use of a unique fibre-glass filaments as basis for wounds of cores and braided coverings, consequently are flexible and may be operated



at temperatures up to 1000°F. without charring, which means a 300% overload at usual ratings. Braided sleeves and metal ferrule ends are colored in accordance with R.M.A. resistance code. Pigtail or other terminals are available. Units are self-supporting, suited to point-to-point wiring, available in two sizes: 1/16" dia. core, rated at 1 watt per body inch and ¼" dia. core, 2 watts. Resistance values from ½ ohm or less to 750 ohms per body inch. Lengths up to 500 feet. Among uses: applications calling for a fixed resistance capable of handling considerable wattage; also as heating elements (since they may be operated at glowing red heat). In use, heating element takes a permanent set in close contact with heated part and casing for maximal thermal conductivity.—*Clarostat Mfg. Co., 285-7 North 6th St., Brooklyn, N. Y.*

Testing Set for Sodium Vapor Lamps

New testing set makes it easier for lighting companies to determine if apparently "burned-out" sodium vapor lamps are actually inoperative. Lamp is merely plugged



in set, which operates from 110 volts, 60 cycles, and normal service circuit turned on. If lamp operates after proper cathode preheating period, fault lies in socket or relay. Set consists of a transformer and operating panel, mounted in a housing designed for easy handling. Panel contains the voltmeter terminals, a lamp socket, transformer adjusting taps, a line switch, and a cathode preheating switch.—*General Electric Co., Schenectady, N. Y.*

Variable Speed Timer

New "112R Precision Set Variable Speed Timer" for vulcanizers, tire presses and platen presses, makes possible exact overall timing of the cure and exact sequence of

the various steps and functions of the cure, hence makes it possible to adjust work load so that individual operator works to greatest efficiency. Seven standard gear ratios provide seven ranges of time adjustment, for each of which there are 80 different speeds of cam revolution. Adjusting the timer from one speed to another is said to be easily and quickly done by hand. Closed mercury switches, eliminating open contacts, are connected to solenoid air pilot valves of the lock-in type so that in case of electrical failure during a cure, the valve will not change position. Done away with are: air pistons, over-running clutches, friction drives and limit switches.—*Taylor Instrument Companies, 95 Ames St., Rochester, N. Y.*

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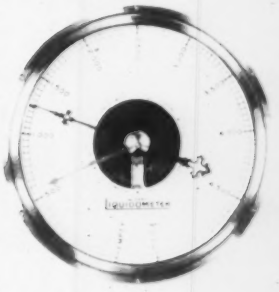

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THE LIQUIDOMETER CORP.
36-27 SKILLMAN AVE. LONG ISLAND CITY, N. Y.

EDITOR'S NOTE—Typical of the air transport industry's tradition-defying spirit is the novel panel mounting of testers, shown on this page. After twice visiting the Cheyenne shops, we suggest that subscribers interested in maintenance apply to United for permission to visit them. Meanwhile, through the kindness of Vice President Harold Crary, we are able to publish this timely article.—MFH

THE FRONT-COVER PHOTOGRAPH shows the dust-proof room [illegible] for the overhaul and repair of gyroscopic devices and ultra-sensitive [illegible] ments such as altimeters, air speed indicators, etc., in the United Air [illegible] instrument shop, Cheyenne, Wyoming. The benches in this room w[illegible] signed and built by United engineers to meet the needs of this par[illegible] type of work. On the two benches in the left foreground are motor [illegible] oscillating plate units designed by United personnel, whereby gyrosco[illegible] struments can be tested in a manner simulating actual flight ope[illegible] Several benches are equipped with special manometers for calibrating [illegible] ous types of instruments. In the rear of the room can be seen equipmen[illegible] for testing manifold pressure gages, barographs, altimeters and flow[illegible]

United Air Lines' Instrument Servicing

By FRED HUNTER

General Offices, United Air Lines, Chicago, Illinois

FROM the two great 1200-horse-power engines, which had been idling lazily, rose a deep-throated crescendo of irresistible power as the pilot opened his throttles and sent the twelve-ton transport plane flashing across the runway on the take-off of the "Continental" from the New York Airport.

A few moments later, the huge plane had found its cruising level and its twin engines were carrying it three miles a minute through the air toward Chicago on the first lap of United Air Lines' overnight sleeper flight to the Pacific Coast.

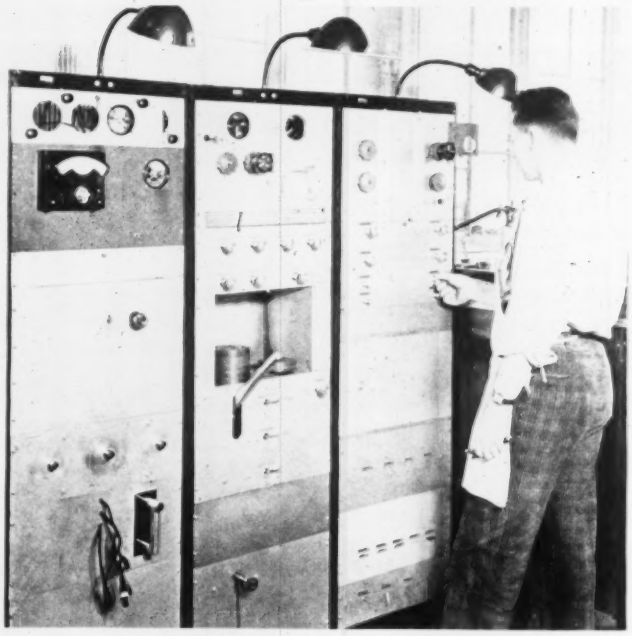
Within the cabin the passengers made themselves comfortable with the assistance of a stewardess who seemed to anticipate their every want. Presently, the stewardess opened her galley in the forward section of the big sleeper plane and prepared to serve a full-course hot dinner. Up in the control cabin the pilot was preparing to radio his first report to the ground, a report that read something like this:

"Smith in 362. Over Allentown range station. 8000 feet. Above overcast, slightly broken, estimated 5000. Speed 192. Compass heading 270. Estimated wind 12 miles an hour northwest. All OK."

When the passengers boarded the plane in New York the weather had been gloomy and unpleasant, but up here, at 8000 feet, the big plane skimmed along at the "sunshine level," where it was calm and clear and smooth. Passengers looking out the windows toward the ground saw only the top of the overcast, which was the "roof," so to speak, of the weather they had just left behind.

That no landscape markings were visible was a matter of complete unconcern to the two pilots. For the modern transport pilot is an instrument pilot. He has learned to trust his instruments more than his senses—because instruments do not fail and, as everyone knows, the human element occasionally does.

As the twelve-ton craft continued its 192-mile-an-hour flight westward, the pilots held their course perfectly by following their radio directional signals and keeping their eyes on the instrument panel before them. Two altimeters told them how high they were flying, offering visible evidence that they were at least half a mile above the highest terrain in the area over which they were flying. Their artificial horizon told them they were flying directly in the path of flight they had selected. Their inclinimeter told them the progress of their flight in rate of ascent and descent and their bank-and-turn indicator told them exactly how their craft was flying, in terms of turn movements. And nearly a hundred other instruments were indicating or recording the performance of the plane, of its engines and of its accessories, so that during every second the pilots could tell at a glance precisely how the flight was proceeding.

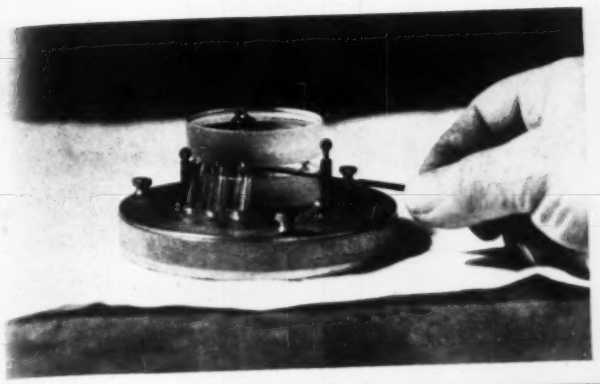


On these three panels special equipment is mounted for testing tachometers, pressure gages and vacuum gages. For this kind of work, the panel structure has proved superior to a bench or table. Both electrical and mechanical tachometers can be tested. An improved type of dead-weight tester (partly concealed) is conveniently operated from the front of the center panel. It and the manometers make it possible to check accurately pressure-measuring and vacuum-measuring aircraft instruments of any range.

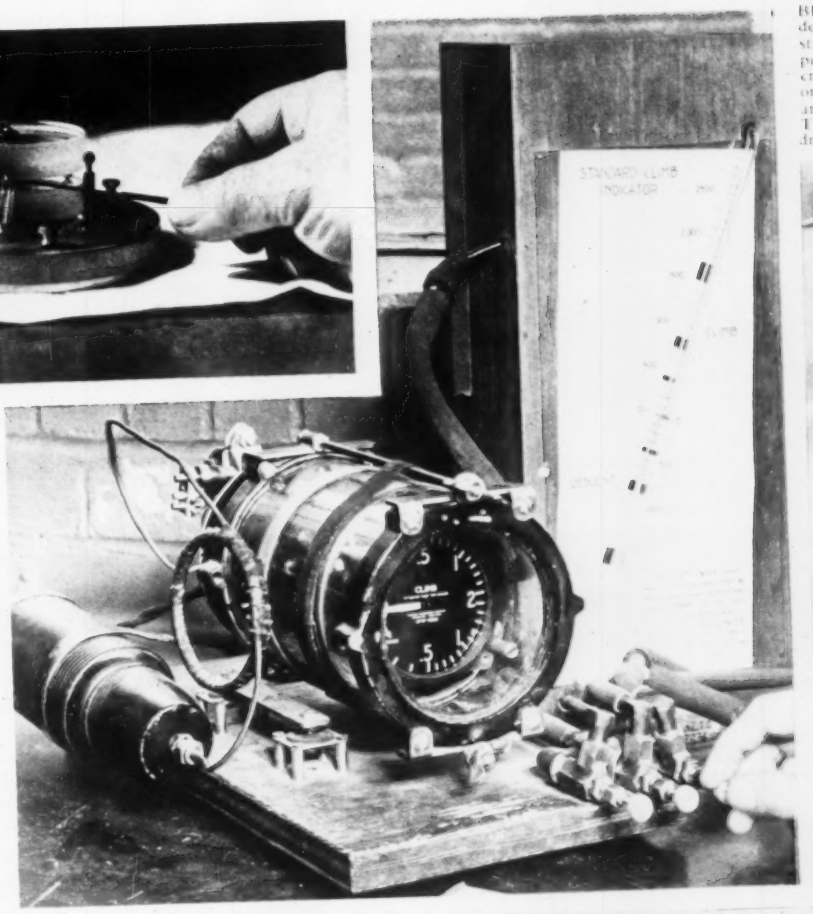
To be sure, there were only two pilots in the cockpit of the big Mainliner slipping through the air so easily and speedily, but actually thirty other men in the instrument overhaul and repair shop out in Cheyenne, Wyoming, were playing as important a part in providing the safe and sure operation that marks transport flying in the United States.

In air transport operation, Accuracy and Dependability are the twin watchwords in the rigid code of instrument procedure. Pilots have come to trust their instruments because they know they are accurate and because they know they will not fail. The accuracy requirements for instruments in air transport operation are considerably greater than those for most other types of flight operation. For this reason it has been necessary for the airlines to set up instrument overhaul and repair shops capable of performing the finest and most accurate work. To do this, much special test equipment had to be developed by the airlines' own engineers; and instrument technicians had to be trained by the airlines themselves for this particular type of work.

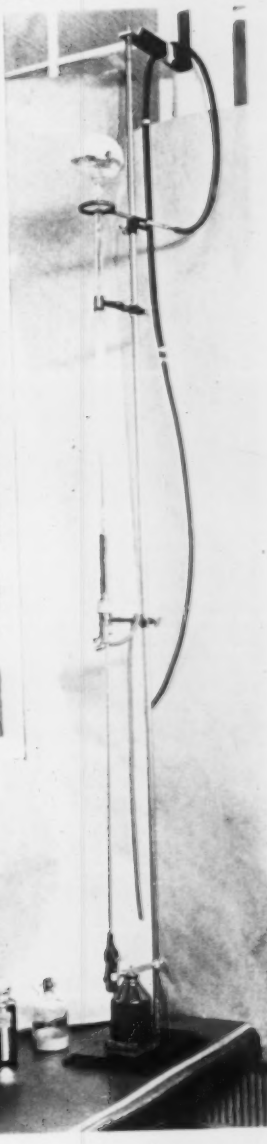
In many instances the accuracy required for instrument equipment by airlines such as United exceeds that of the manufacturer, or of the military services. For instance, the altimeter calibration limit for all elevations between sea level and 6,000 feet is ±15 feet. When it is considered that the total range of these instruments is 20,000 feet, it readily can be understood that an accuracy of ±15 feet is an exceedingly close tolerance.



TOP—Special instrument developed by United's instrument shop for grading bearing balls used in gyroscopic instruments by the use of quartz optical flats. It is set up to check uniformity of size and trueness of sphericity—not for measuring diameters. Through its use, steel balls are graded to a few millionths of an inch. Use of these quartz optical flats enables United to assort bearing balls into exquisitely-matched sets so that even at 15,000 r.p.m., gyroscope rotors run perfectly true.



CENTER—One of the individual-instrument agitated pressure chambers designed in United's instrument shop for testing barometric scales and balance on altimeters as well as calibrating rate-of-climb indicators. This test hookup consists of a master rate-of-climb indicator and an agitated pressure chamber. Due to the geographic location of the shop, the altimeter calibration is accomplished here in a manner somewhat different from the usual practice near sea level: At Cheyenne, United starts at the 6,200-foot pressure, proceeds down to sea-level pressure and, finally, up to the upper (lowest-pressure) range.



BELOW—Mercury reclaiming device built by United's instrument shop. The need of pure mercury is steadily increasing for barometers, manometers, etc., some of which are used as shop standards. Therefore, United frequently drains and refills instruments.

Even some new instruments are recalibrated in the overhaul and repair shop before they are placed in service. This is not a reflection upon the manufacturer; and is only mentioned to show how the air transport operator takes infinite pains to have equipment that will satisfy the extremely rigid standards of performance that he has set up for his particular type of operation.

Modern aviation instruments may be classified according to their uses: (*a*) navigation, (*b*) automatic piloting, (*c*) instrument landing, (*d*) automatic instrument landing, (*e*) powerplant control and (*f*) ice warning.* They may also be divided into four principal classes: (1) pressure, (2) electrical, (3) magnetic and (4) gyroscopic. In these four main classes—not counting lesser ones—there are thirty different types. Because of this, United's instrument overhaul and repair shop in Cheyenne represents a highly specialized industry. Although competent to work on any instrument and qualified to handle any problem that comes into the shop, each technician soon becomes a specialist in a certain type of instrument and is assigned to it.

Instrument technicians don't grow on trees and the United instrument shop has found that it must train its own technicians. In charge of the shop is L. D. Bean, who has been with United since 1930.

Foreman Bean came into the Cheyenne instrument shop from the watchmaker's bench. Because they have acquired facility in working with small parts, watchmakers frequently make good instrument mechanics. But watchmaking ability is not enough to make a good instrument mechanic and an experiment in limiting new apprentices to watchmakers did not work out: a number of them failed to show sufficient adaptability to go on into the more intricate work of aircraft instrument repair.

Instrument technicians have to have a knowledge of spring strength, spring travel, linkages and kinematics in general, as well as pressure-measuring theory and equipment, electricity and other technical subjects, as well as the ability to work with small parts, if they are to turn out the character of work required by the air transport lines.

The instrument overhaul and repair shop in Cheyenne is divided into two divisions, one charged with servicing instruments and the other with repair.

Instruments, like engines, are overhauled at regular intervals. Cheyenne is the location of United's central maintenance base and each of the line's $\frac{5}{8}$ twin-engined Mainliners is routed into Cheyenne after each 500 hours of service. On these occasions, the engines are completely dismounted and the airplanes stripped down. Every instrument aboard is removed and goes into the instrument shop for a complete check and overhaul and such repairs as may be necessary.

Continued on page 327

*W. G. Brombacher, What Instruments Do for the Air Transportation Industry, *Instruments*, Vol. 12, Jan. 1939, pages 43-46.

New Method of Testing Accelerometers

By B. W. WOOLARD
National Bureau of Standards, Washington, D. C.

ACCELEROMETERS are ordinarily calibrated by subjecting them to centripetal accelerations on a rotating turntable. This gives no information on the performance of the accelerometer when subjected to accelerations fluctuating from a minimum to a maximum in a period less than about 20 times the natural period of vibration of the sensitive element of the accelerometer.

One way of obtaining some information on the response of the accelerometer under these conditions has been to subject it to an approximately simple harmonic acceleration obtained by a reciprocating motion. When the natural period of the accelerometer and of the imposed acceleration are both relatively high, the requisite apparatus is large and cumbersome. Moreover, test values are not obtained for conditions equivalent to those met in practice, in that the reciprocating apparatus must be brought up to speed so that the response of the accelerometer can be obtained only for a steady condition of oscillating accelerations.

Another method especially suitable for relatively high frequencies has been developed by the National Advisory Committee for Aeronautics[1] in which the instrument, falling freely, is stopped by a deflecting helical spring.

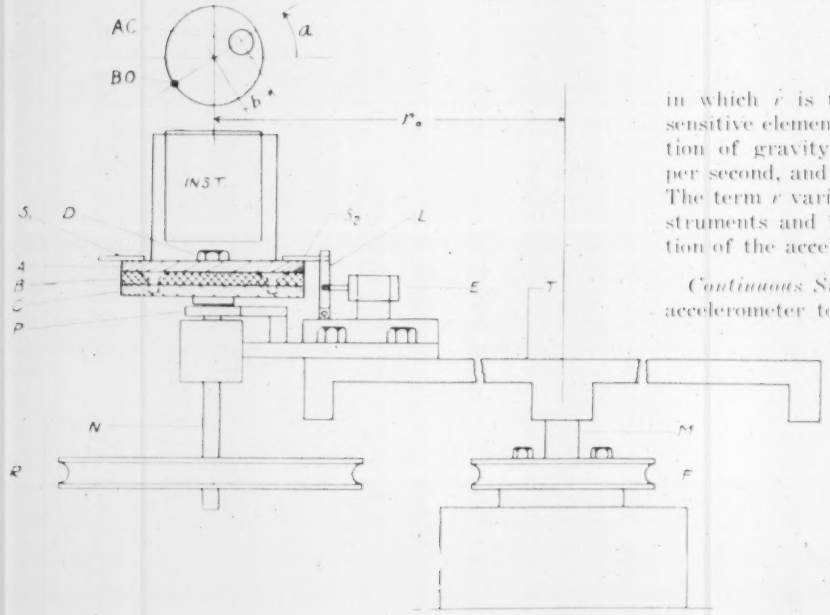
A new method is described by means of which single-component accelerometers can be subjected to practically simple harmonic acceleration which is either continuous or has a duration of a selected part cycle or number of cycles. The frequency and amplitude of acceleration are controllable within reasonably wide limits.

The apparatus was constructed at the request and with the cooperation of the Bureau of Aeronautics of the Navy Department.

DESCRIPTION OF APPARATUS

The turntable apparatus is modified by the addition of a system of two belted pulleys, one fixed to the stationary base of the turntable; the other located at the rim of the turntable and free to rotate about its own axis. The accelerometer is mounted upon a plate connected to the rim pulley by means of a friction clutch.

[1] James V. Hootman, A method for the dynamic calibration of accelerometers, Presented before Virginia Academy of Science, May 6, 1938.



In Fig. 1, T is a turntable driven through shaft M by variable-speed motor; F is a fixed pulley bolted to the fixed base of the turntable and concentric with the turntable shaft M; N is a shaft, parallel to shaft M, supported by a housing rigidly attached to the rim of the turntable; R is a pulley and C a flat plate covered with brake lining B rigidly attached to shaft N; A is a plate upon which the accelerometer is mounted, and which is concentric with but not secured to shaft N. The friction between A and B is adjustable by means of nut D. Pulley R is interchangeable with others having different diameters. It is driven by pulley F by means of a belt.

Plate A is stopped from rotating about its axis by contact of either strip S_1 or S_2 with stop L. Stop L can be pulled out of contact with either S_1 or S_2 by energizing the electro-magnet E by throwing a switch on the control panel. The necessary electric current is brought to turntable T by slip rings on shaft M. Current for operating a buzzer for vibrating the accelerometer under test is conducted to the buzzer through slip ring P.

It is essential that the turntable axis be vertical. Fig. 2 shows the apparatus at the National Bureau of Standards. Turnable T is of cast iron, three feet in diameter. Its rate of rotation is measured by a calibrated tachometer, and is controlled by a variable-speed d-c. motor and (not shown in the figure) a foot-operated brake.

OPERATION

Steady Acceleration. To subject the accelerometer to a constant acceleration it is held in a fixed position relative to the turntable. Ordinarily it is mounted in one of the five mounts on the turntable shown in Fig. 2, when obtaining a simple calibration. When a comparison is to be made with the indication obtained when subjected to the simple harmonic acceleration it is mounted on plate A (Figs. 1 and 3) which is held fixed relative to the turntable.

In calibrating the accelerometer, the turntable is slowly brought up to the speed corresponding to a desired acceleration. The reading of the instrument may be recorded by a camera, operated by a solenoid, by a maximum-indicating pointer if the instrument is so equipped, or by the record obtained if the instrument is a recorder.

The acceleration A in g-units corresponding to the speed of rotation n of the turntable is given by the relation

$$A = \frac{4\pi^2 n^2 r}{g} \qquad (1)$$

in which r is the radius of rotation of the acceleration-sensitive element of the accelerometer and g is the acceleration of gravity. If r is in feet, g is in feet per second per second, and n in revolutions per second, A is in g-units. The term r varies measurably with acceleration in some instruments and in this case must be determined as a function of the acceleration.

Continuous Simple Harmonic Acceleration. To subject an accelerometer to this type of acceleration, plates A and C (Fig. 1) are clamped together, and stop L is held back out of contact with strips S_1 and S_2. A belt connects pulleys R and F.

Fig. 1. Diagram of Test Apparatus. T is a motor-driven turntable; F is a stationary pulley; R is the rim pulley; P is a slip-ring; plates C and A and brake lining B constitute a friction clutch adjusted by nut D; S_1 and S_2 are metal strips which impinge on stop L; and E is an electromagnet. BO is a reference mark on an accelerometer, the sensitive element of which is indicated by AC.

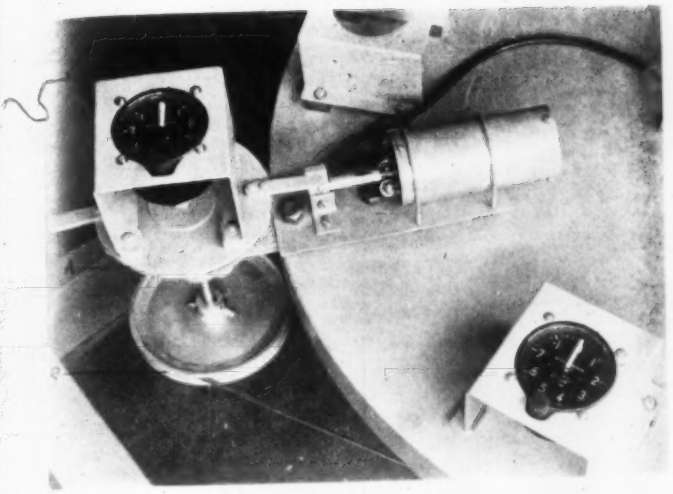


Fig. 2. Accelerometer test equipment at the National Bureau of Standards. *R* is the rim pulley and *A* is the plate upon which accelerometer is mounted.

The instrument is mounted so that its center coincides with the axis of rotation of pulley *R*; or if the motion of the acceleration-sensitive element is small relative to the radius of the turntable, it may be mounted with the center of gravity of the element coincident with the axis.

As the turntable rotates, pulley *R* and the accelerometer also rotate with respect to the turntable. The acceleration imposed on the instrument is approximately constant in magnitude but varies in direction with respect to the instrument. A single-component accelerometer will be affected only by the component of this acceleration in the direction of the sensitive axis of the instrument. The variation of this component of acceleration will be nearly sinusoidal. The successive positions of the instrument during one revolution are shown diagrammatically in Fig. 3 in which the dot is a reference mark for indicating the orientation of the instrument. Pulleys *R* and *F* are shown of equal diameter. At positions (1) and (3) in Fig. 3, the black dot indicates that the imposed centripetal acceleration is at right angles to the direction in which the acceleration-sensitive element is free to move and therefore the active component of the imposed acceleration is zero. In positions (2) and (4) the imposed acceleration is maximal; the imposed accelerations are equal but opposite in sign. At intermediate positions, components of the imposed acceleration actuate the instrument. The active component of the acceleration varies as shown in Fig. 4.

For equal-size pulleys it is evident that the frequency *f* of the acceleration cycle is equal to the frequency *n* of the turntable rotation. The frequency is controlled by varying the diameter of pulley *R*. In this case

$$f = n D_F / D_R \qquad (2)$$

where *n* is the rate of rotation of the turntable, *f* is the frequency of the simple harmonic acceleration, D_F and D_R are respectively the diameters of pulleys *F* and *R* (Fig. 1).

The frequencies obtainable for two accelerations with four pulleys used at the National Bureau of Standards are given in the table below. Frequencies at other accelerations can be computed from equations (1) and (2).

Acceleration *g*-units	Frequency per Minute — Pulley ratios D_F/D_R			
	0.60	0.78	1.00	1.82
3	43	55	71	129
6	61	78	100	182

If the accelerometer is of the single-component type (sensitive only to that component of the acceleration of the instrument which is in the direction of the acceleration-sensitive axis, fixed in the instrument) the effective imposed acceleration *A* in *g*-units, is given approximately by

$$A = \frac{4\pi^2 n^2}{g} r_c \cos a - \frac{4\pi^2 b}{g} (n - f)^2 \qquad (3)$$

where r_c is the radius of revolution of the center of the case, *a* is the angle between the acceleration-sensitive axis of the instrument and the radius of the instrument coincident with the radius of the turntable measured as shown in Fig. 1, *n* is the rate of rotation in r.p.s. of the turntable, *g* is the acceleration of gravity, *f* is the frequency of rotation in r.p.s. of pulley *R* with respect to the turntable as defined in Eq. (2), and *b* is the displacement of the acceleration-sensitive element from the center of the instrument. The displacement *b* is measured along the acceleration-sensitive axis and is positive if the acceleration-sensitive element is above the center of the instrument when the instrument is in the normal dial-vertical operating position as indicated in Fig. 1, top view, where *AC* represents the acceleration-sensitive element and *BO* marks the bottom of the instrument when it is in the normal dial-vertical position. It is a function of the indication of the instrument at the moment of observation and must be computed or measured for each design of accelerometer.

The last term in Eq. (3) is a correction term for the shift of the acceleration-sensitive element from the center of the instrument. It should be noted that $(n - f)$ is the rotational speed of the instrument about its axis with reference to the room, not with reference to the turntable. When the instrument does not rotate with respect to the turntable, *f* is zero and the correction term is $4\pi^2 b n^2 g$; when frequency *f* equals *n*, the correction term is zero. For a typical maximum-indicating accelerometer the correction was found to be of the order of one or two percent.

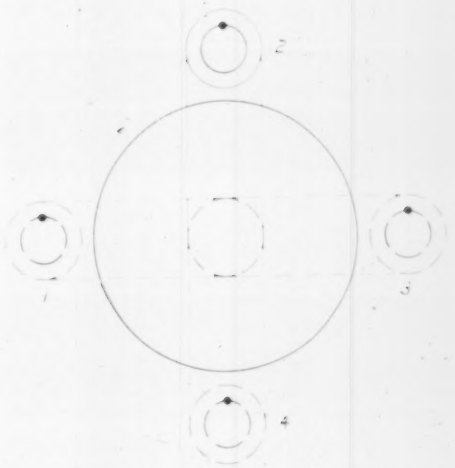


Fig. 3. Arrangement whereby a simple harmonic acceleration is continuously imposed upon accelerometer. Reference dot on instrument shows how the accelerometer rotates about its own axis with respect to the turntable. The effective component of the acceleration is thus varied as shown below.

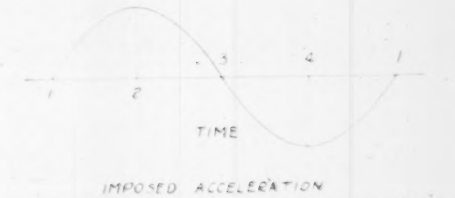


Fig. 4. Resultant variation of effective component of acceleration

The variation of imposed acceleration will be nearly sinusoidal provided that the accelerometer is a single-component instrument. If the displacement *b* of the acceleration-sensitive element is not a linear function of the acceleration, there will be deviations from sinusoidal variation of the imposed acceleration. These deviations will be small since they appear as irregularities in the relatively small term containing *b* in Eq. (3).

Part Cycle of Simple Harmonic Acceleration. To subject a single-component accelerometer to a part cycle or number of cycles of simple harmonic acceleration, the friction clutch

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New Applications of Variable-reluctance Method to Aircraft Instruments

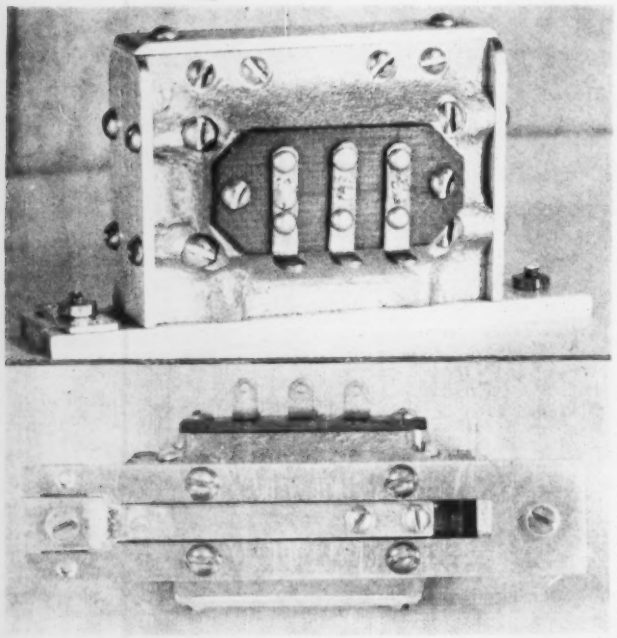
By H. H. BRUDERLIN

Development Engineer, Douglas Aircraft Company, Inc., Santa Monica, Calif.

STRESS measurements in aircraft are of extreme importance to safety, both as they affect design for static loads and as means of determining the effect of vibration and shock loading upon parts of the structure. Some early airplanes, whose strength was based upon estimated requirements alone, did not fare well in service. Landing gear failed frequently, wings and tail surfaces were known to flutter occasionally, and once in a while an engine would release itself from the airplane. Measurements in the field have been found necessary to verify design theory on each new model.

Such investigations require considerable accuracy and must often be made under extremely difficult conditions. Stress and vibration measurements are often needed in the wings, engines, or tail surfaces, where the primary measuring element is remote from the observers. Accurate determinations of combined static and dynamic stress may be required under all conditions of temperature and vibration, where even the order of magnitude is not known before the test flight is begun. The importance of transients and the high cost of operating an airplane impose additional limitations upon the type of equipment that can be used.

No one instrument is flexible enough in its applications to meet satisfactorily all the needs of the test engineer. Four distinct types of primary measuring devices are required, with means for simultaneous recording at a central point so that the records may be studied at leisure. Such pickups all have essentially the same mechanism, consisting of a spring suspending a weight from a mounting base, with means for measuring the movement of the weight with respect to the base. Choice of springs and measuring means fixes the characteristics of the pickups.



A—Full-size illustration of accelerometer with strain gage attachment, latter consisting of special base plate as shown in lower photograph. Total weight, 6½ oz.

For determining load factor, or number of times gravity load, applied to a structure during landings, dives, and various maneuvers, an accelerometer is required. This is a spring-controlled device, having a resonant frequency well above its operating range, and a means for indicating the displacement of the suspended mass from its normal position. It may be made to measure both static, or steadily applied gravity factors, and dynamic, or vibrational accelerations. The crystal vibration pickup is a common example of electric accelerometer, although not suitable for measuring sustained load factors.

The output of an accelerometer when used as a vibration pickup is $E = K a f^2$, where a is amplitude and f is frequency. In many applications this characteristic serves

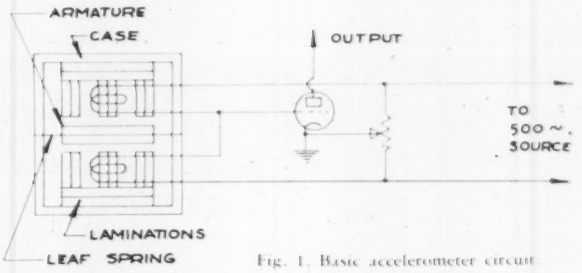


Fig. 1. Basic accelerometer circuit

to over-accentuate high frequencies to an objectionable degree. For general vibration work, an accelerometer is therefore not as suitable as a type of pickup which measures velocity. The output of the latter is $E = K a f$, making it more useful for wide range testing. Velocity pickups are generally constructed with a magnetic field and a generating coil, one being fixed to the base and the other to the suspended mass, and have a resonant frequency well below their measuring range. The mass, which remains "stationary," serves as a fixed reference point.

For measuring slow vibrations of small amplitude where much high-frequency vibration is present, or for determining the deflection of members under steady load, an instrument having a response independent of frequency is indispensable. This condition, $E = K a$ is, of course, fulfilled when we measure amplitude, or displacement, directly. In the first case, this is done by making the spring flexible enough so that the natural frequency is well below the operating range as in the velocity pickup; the mass remains stationary and its displacement with respect to the base is measured. In the case of sustained deflection this arrangement is obviously not feasible: the base must be fixed to a reference point and the mass to a point at which the displacement is to be measured. Such a device is commonly termed a strain gage or extensometer.

Two years ago a situation arose which required a "good" electrical accelerometer: it had to be small, light, extremely sensitive yet with wide range; it had to furnish accurate signals at a considerable distance; and be uninfluenced by extreme climatic conditions. Nothing being commercially available and our need being urgent, we undertook to build our own.

An accelerometer is fundamentally an instrument for indicating rate of change of velocity, which is ordinarily accomplished by measuring in some way the deflection of a small weight suspended on a relatively stiff spring. How-

, acceleration may change frequently (think of a ball ing over a series of ridges) and if the rate of reversal acceleration is the same as the natural frequency of the ght on the spring, resonance occurs and an exaggerated ding results. If the rate of reversal is faster than the ural frequency of the weight on the spring the weight mains stationary and we are no longer measuring ac- eration.

The first requirement of an accurate accelerometer, then, to have the resonant frequency (since any system having ass and elasticity has at least one resonant frequency) re than twice as high as any frequency at which we may pect acceleration to change. For our case, we chose 140 cles per second as being well out of the operating range.

There is a definite relation between the frequency of a suspended weight and its deflection under any given accel- eration. For a frequency of 140 c.p.s. this amounts to ap- proximately 0.0005" per g. To measure accurately to one- tenth load factor obviously required higher sensitivity than obtainable with any method ordinarily used in stress meas- urement. After considering possible means we settled upon a variable reluctance bridge as the most promising solution.

Our experimental accelerometer and circuit are shown in Fig. 1. A 500-cycle carrier voltage is applied across the bridge, of which the coils form two legs. As the armature approaches one coil it is leaving the other, and the two non- linear outputs combined result in linear swing of the com- mon return. This output is applied through an a-c. amplifier to an indicating or recording device. Overall dimensions of the pickup were under $1\frac{1}{4}$". The coils were bobbin wound on a special core and as installed had an inductance of 1.5 henries. The limit of sensitivity was the accuracy to which we could balance out the 500-cycle carrier wave in the bridge, which depends upon phase shift and distortion occurring in the coils themselves. Much later we found that shorted turns in the coils were responsible for difficulty experienced in balancing.

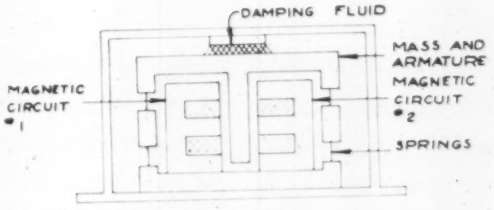
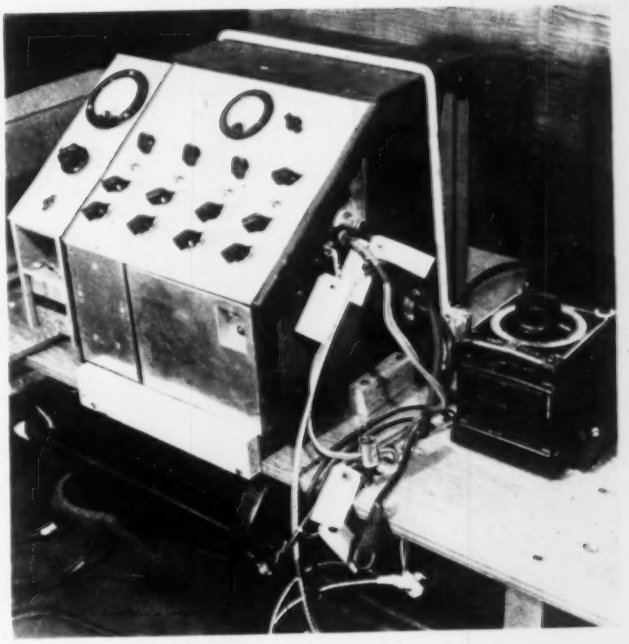


Fig. 2. Present accelerometer.

The present design (Photo "A" and Fig. 2) has been re- vised for greater sensitivity, range, and reliability. Coils are layer wound and have an installed inductance of 1.2 henries. Four flexure pivots are used, mass, armature and springs being machined from one piece of steel. With about 0.007" clearance to coil core, sensitivity using present single-tube amplifiers is better than 0.05 g. and range is $\pm$ 15 g. Fluid damping has been added in a novel manner by filling a small clearance between the moving mass and the fixed case with a thick viscous material having an excellent tempera- ture-viscosity characteristic. With approximately 0.7 of critical damping, the output of the instrument is practically linear up to $\pm$ 10 load factors at frequencies as high as 90 c.p.s., making it quite useful as a pickup for low-frequency vibration as well as for measuring sustained accelerations. Sensitivity may be varied merely by adjustment of the amplifier gain. The bridge is always operated at such a point that peaks will not cause it to approach a balance too closely.

The variable reluctance principle has for a number of years been used successfully in sensitive strain gages. The new accelerometer was designed in such a way that all that is necessary to make a strain gage of it is to remove it from the case and insert needles at points corresponding to the desired gage length, holes being provided in the frame with $\frac{1}{4}$", $\frac{1}{2}$" and 1" spacing. With present equipment it can easily measure to an accuracy of 30 lbs. in.^{2} in steel.



"B"—Complete equipment except pickups, for producing four simultaneous records, in the cabin of the DC-4 airplane. The main instrument (with symmetrical control panel) is a combination four-channel amplifier with bridge balancing, gain, and monitoring controls. The narrow unit (at left) is the four-element recorder with film drive, switch, and film speed indicator.

In the presence of vibration the strain gage is made insen- sitive to accelerations by mounting it according to the prin- ciples set forth in the *Bureau of Standards Journal of Research*.[1] Excellent results have recently been obtained by operating the accelerometer bridge directly from a 110-volt 500- to 2000-c.p.s. supply. The rectified output is sufficient, without amplification, to be read directly on an output meter or to actuate a sensitive oscilloscope galvanometer.

After these instruments had been in use for some time it became necessary to measure torsional vibration of an air- plane wing at a fairly low frequency. Acceleration measur- ing devices are not particularly suitable for this purpose because of their characteristic of favoring the high fre- quencies and because the axis about which we were meas- uring was so far from the wing itself that it was impossible to get enough differential between two pickups installed at different points to make certain that it was the torsional

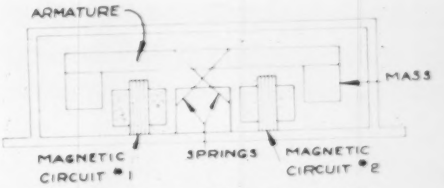


Fig. 3. Torsional displacement pickup.

vibration that was being measured. We therefore devised a similar instrument, still using a balanced inductance bridge, that responded to torsional but not to linear motions. Here again we used flexure pivots. In this case the spring con- stant was adjusted so that the resonant frequency of the armature was well below any that we desired to measure, giving a torsional displacement measuring device. Being partial to low frequencies, it was thus more suited to our purpose than a torsional accelerometer would have been.

A pickup of this type was also a great deal more difficult to build than a torsional accelerometer would have been.

[1] W. M. Bleckner, Compensation of Strain Gages for Vibration & Impact, *Bureau of Standards Journal of Research*, Vol. 18, June 1937, pages 723-737.

The "catch" lay in a type of suspension having low hysteresis, low spring constant, a fixed pivot point, and sufficient rigidity against linear forces. Beldon springs were adopted after several types of bearing pivots were tested and discarded. The pickup shown in Fig. 3 has a resonant frequency of between one and two cycles a second. Damping is provided in the same manner as in the accelerometer. The pickup measures angular vibrational deflection accurately at all frequencies above 200 c.p.m. with a range of ±3° and an accuracy of better than one-half minute.

Ordinarily a linear displacement pickup is out of the question for aircraft use, because of the high amplitudes encountered. Vertical low-frequency wing vibration, for example, may occasionally have an amplitude of more than 6". In order to measure this by present methods we must have a pickup large enough to allow a suspended mass to remain stationary while the case in which it is mounted moves the full amplitude of the wing tip. The natural frequency of the mass on its mounting spring must be well under one cycle per second. Difficulties involved in the construction and use of such a machine are obvious.

A linear displacement pickup, having characteristics similar to those of the torsional instrument described above, may be made by mounting side by side two torsion pickups that are slightly off-balance. A perfect balance wheel will not respond to linear forces, but if it is given a small unbalance it will rotate when the pivot is displaced linearly. We may control the resonant frequency of the system by adjustment of the moment of inertia and restoring spring constant, and we may control its response to linear forces by the amount of unbalance we apply. By the elementary laws of physics the percent response of such a wheel is the same as the per cent unbalance: if a wheel has 5% unbalance at a given point, that point will move, with respect to its pivot, 5% of the linear amplitude of the pivot. Two of these may be connected in such a way that response to rotational motion will cancel out. An amplitude of 4" may thus be reduced mechanically to an amplitude of 0.2" and measured with an accuracy of 0.5% in a device whose longest dimension is 3".

When measuring vibration, it usually is most advantageous to use a pickup having an output proportional to velocity rather than to displacement or acceleration. Such a pickup favors neither the high nor low frequencies, since its output is proportional to the product of amplitude and frequency and is thus a measure of the energy being imparted to, or radiating from, a vibrating body. Measurement of vibration velocity may be made with the torsional pickup described above by using direct current excitation. Velocity measurements are obtained with the accelerometers in two ways: (1) by highly damping the armature magnetically or hydraulically so that the moving parts are essentially resistance controlled,* and (2) by integrating the output of the accelerometers with an electrical integrating circuit. In the latter case the frequency range is limited at the lower end by characteristics of the integrating circuit and at the upper end by those of the accelerometer suspension. With the highly damped armature, however, the frequency range is almost unlimited; and thus we may have a pickup incorporating all of the advantages of a moving-coil type with none of the disadvantages.

Use of the variable reluctance principle requires a high frequency a-c. source of constant voltage. After some experimental work a stabilized tuning fork oscillator was chosen for this purpose. The fork has a frequency of 500 c.p.s. and is driven magnetically. Feedback is used on the single 38 tube employed, to provide rapid starting and constant output under varying load and power. The output of this oscillator is distributed to four bridge circuits by a special transformer having four electrostatically shielded secondary windings. A second self-excited relaxation oscillator is fed by a portion of the output of the 500-cycle oscillator in such a way that relaxation occurs every tenth cycle of the latter, giving a 50-cycle sharply-peaked wave that is used to provide a timing trace.

Since in the present apparatus four channels are used simultaneously, it was necessary to alter the original circuit as shown in Fig. 4. One control is for amplitude or range and the other for balance. Each pickup has its own input winding, controls, amplifier, and rectifier. The amplifier consists of one power stage and one stage of voltage amplification which is used in conjunction with an integrating circuit and which is normally bridged. The power amplifier, a 38 tube, operates through a transformer into a full wave rectifier, a 6ZY5 tube, and the output of this is filtered free of carrier wave and recorded. Efficiency of the rectifier is approximately 50%, and the output impedance is of the order of 600 ohms.

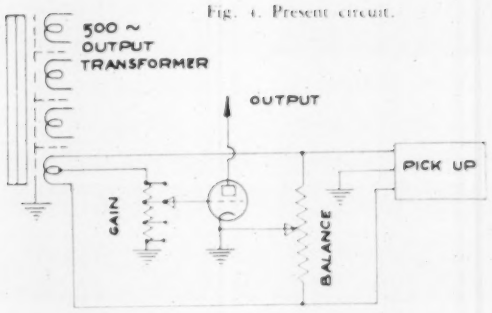


Fig. 4. Present circuit.

Power is from 110-volt 60 cycle source. To supply this a motor generator is used, operating from 12-volt batteries which are standard equipment in present airplanes.

With this equipment it is possible to record simultaneously from four separate sources. Photo "B" shows such equipment in the DC-4 on a flight test. All controls are arranged on one panel so that any combination of pickups, timer, or other type of signal may be recorded. An output meter may be switched into any circuit to provide simultaneous visual indication while recording and to aid in balancing the bridge. Sufficent power is provided by the amplifier to drive a string oscillograph or a crystal pen recorder. Excellent results have been obtained from the equipment on a number of test flights.

*Suggested by Mr. D. P. Love, Electrical Research Products Inc.

A New Method of Testing Accelerometers

Concluded from page 324

is adjusted so that plate A can be held from rotating by stop L while plate C is rotating. The accelerometer is mounted so that its pointer does not deflect under the acceleration while A is kept from rotating. The belt connection between pulleys R and F is in place. When the turntable is brought exactly to the speed corresponding to the desired acceleration, electromagnet E is operated, pulling stop L out of contact. Plate A then rotates with respect to the turntable. The rotation is stopped when plate A has revolved for the desired fraction of a revolution or number of revolutions by releasing the electromagnet to return stop L to position.

It is obvious that by eliminating one strip S or by selective operation of the electromagnet, one or more cycles, as desired, of simple harmonic acceleration can be imposed on the accelerometer.

Control of the amplitude and frequency of the imposed acceleration, as well as the correction for local rotation, have been discussed in the previous section on "Continuous simple harmonic acceleration."

The speed of rotation of the turntable increases somewhat as the frictional drag of the friction clutch is removed by allowing plate A to rotate. The foot-operated brake previously mentioned can be set to give a compensating friction and then be put into operation simultaneously with the friction clutch.

As the local rotation is stopped the instrument is subjected to a negative acceleration by the impact which may in some instruments mask the result desired. This is minimized by interposing shock-absorbing material, such as sponge rubber, between stop L and strips S_1 and S_2. If a recorder is tested, or a photographic record of indication is obtained, running several cycles will separate this effect from the reading desired.

United Air Lines' Instrument Servicing

Concluded from page 321

This inspection procedure is so thorough that United engineers have had to design, develop and manufacture much of the special testing equipment, either because the needed equipment was not available or because it would have been too expensive to have it built specially on the outside, by companies located far from Cheyenne.

Instrument overhaul in United's Cheyenne shop is more than a matter of correcting irregularities of performance. The aim is to provide a rigid inspection and testing procedure that will "head-off" possible failures or irregularities.

The instrument shop proper in Cheyenne, of course, is a dust-proof room. Even so, glass covers are much in evidence to cover up instrument parts which must remain in the open. A filtering system is employed to further reduce dust particles to a minimum, but every precaution is taken with each individual instrument, including the glass coverings.

Instrument upkeep and repair by the airlines has reached such a high point of efficiency that the report of an instrument variation has become a rare occurrence. Each transport plane, for instance, is equipped with two altimeters. Since pilots at all times must be clearly aware of their altitude above terrain two instruments are installed in each ship so that they may be checked against each other and so that the pilots would have a spare altimeter if one by chance should go out. Almost invariably, because of the fine precision work performed in the instrument shop, these twin altimeters are found to coincide perfectly throughout their service periods.

Like most of the other branches of air transport, the instrument shop never has a chance to rest on its laurels. New instruments and new methods and new improvements in old instruments and old methods constantly are being devised, and the instrument overhaul and repair shop has to keep as modern as tomorrow's newspaper.

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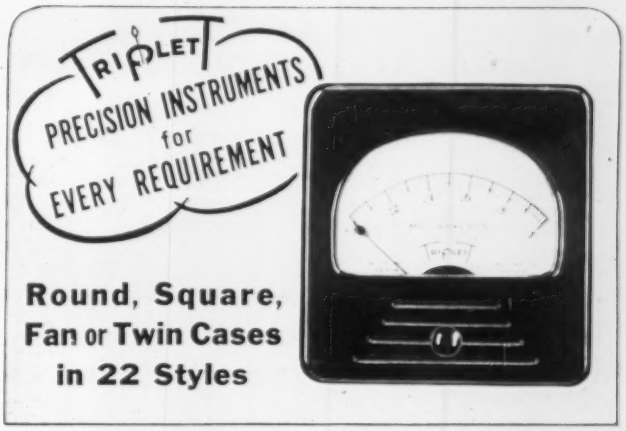

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